Popular Astronomy

Vol. XLVI, No. 9 NOVEMBER, 1938 Whole No. 459

A Meteoritic Hypothesis of the Origin of Continents

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The present treatise is intended to furnish an outline for an explanation of the distribution of land areas on the earth's surface. Its extension would afford a suggestion for the origin of the moon and perhaps the "canals" on Mars. The writer is conscious that a criticism of this publication in its present form may be that it is premature. His reasons for publishing this outline at the present time are that:

1. He is engaged in research work in another field at the moment, and is consequently unable to attempt the detailed investigations necessary at present;
2. Such a suggestion for the origin of the continental masses would affect one line of investigation in the work he has in hand; and
3. The proper development of such an hypothesis depends upon the availability of data not readily accessible in several related branches of science, and can be best undertaken by the coöperation of those authorities in the particular fields concerned. By presenting a new viewpoint, this hypothesis might, even in its present form, afford the means for the successful attack on some of the problems still awaiting solution.

The current theories of the origin of the solar system are the Planetesimal Hypothesis of Chamberlin and Moulton and the theory of Sir James Jeans; but there is apparently no satisfactory hypothesis to account for the origin of our satellite the moon. It is interesting to consider what the consequences might have been to the earth, had it passed through a sufficiently dense swarm of meteorites at about the close of Archaean times. That such a mass of planetary débris could have existed is consistent with current theories.

The present velocity of the earth in its orbit around the sun is about 18.5 miles per second, and in an hour it travels about 67,000 miles. From our present knowledge it seems likely that, at the time in question, the earth had a mass and orbital velocity comparable with those it has now, but that it had a shorter period of rotation, perhaps more nearly equal to those of the Jovian planets. Figs. 1 and 2 show the arrangement of the earth-shells as indicated by data from contemporary seismology, and some such arrangement of the earth-shells in Archaean times seems probable. In the process of cooling, solidification of the exterior shell would have occurred first at the surface, forming a crust, composed of material, corresponding perhaps to the present sial, overlying a vitreous shell. This crust, once it had formed, would have pre-

vented the lighter elements, such as some of the gases which now compose the atmosphere, from escaping through it. These elements would have been imprisoned within the lithosphere and absorbed, under considerable pressure, in the molten material below the crust. These conditions would have resulted probably in a rarer atmosphere and, with less oxygen and hydrogen free to form water, a thinner hydrosphere than those existing now. The earth, at the time, might have had one or more tiny

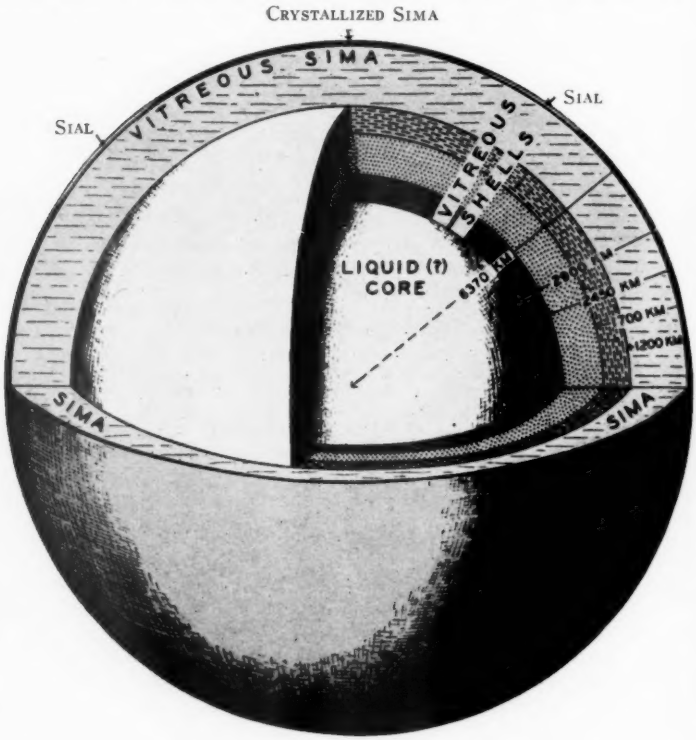


FIGURE 1

STEREOGRAM OF THE EARTH-SHELLS, ACCORDING TO PROBABLE DATA FROM CONTEMPORARY SEISMOLOGY.

Daly's "Changing World of the Ice Age" Courtesy Yale University Press

satellites such as those of Mars. The orbit of the meteoritic swarm would have been possibly elliptical and have lain close to the plane of the ecliptic. The earth's velocity of about 70,000 miles per hour, in a direction approximately perpendicular to that of the meteorites, might have resulted in the duration of the effective bombardment having been about an hour.

Such a bombardment would have had consequences to (1) the earth as a whole, and (2) the crust in particular. If the collision had occurred when the south pole of the earth was inclined towards the swarm, the paths of the meteorites would have been normal to the surface of the earth at a point located near $\phi = -20°$. One hemisphere, together

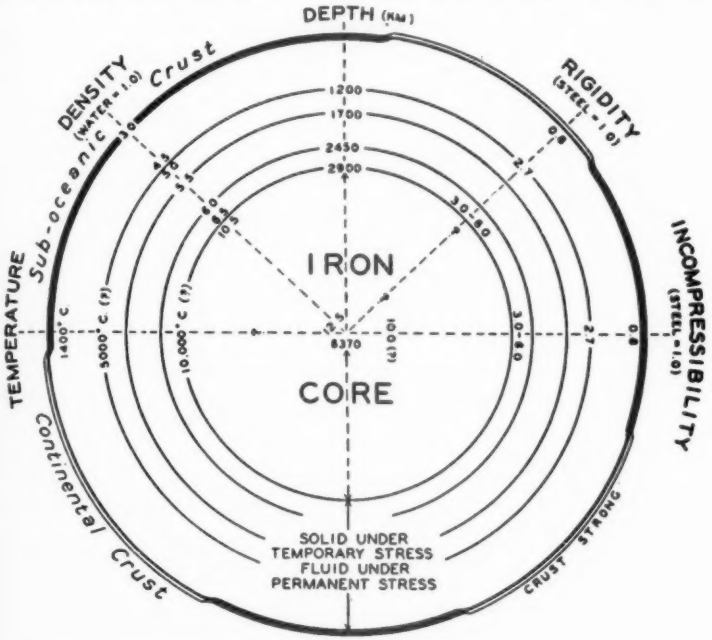


FIGURE 2

CROSS-SECTION OF THE EARTH, ILLUSTRATING THE PRINCIPAL PROPERTIES OF THE EARTH-SHELLS.

Daly's "Changing World of the Ice Age" Courtesy Yale University Press

with the part turned into the swarm by the earth's rotation, would have been exposed, while the rest of the surface would have been sheltered from the effects of the direct impacts of the meteorites. Apart from a slight alteration in the rotational and orbital velocities, the only appreciable effects to the earth as a whole would appear to be that the axis of rotation might have been tilted if the resultant force of the impacts did not pass through the center of mass. Such a displacement, on account of the gyroscopic effect of the earth's rotation, might have tended to produce a slow "wobble" of the axis and might have contributed to effects analogous to the precession of the equinoxes.

The consequences to the crust would have been:

1. Effects on the surface due to the direct impacts; and

2. Stresses in the underlying sial and vitreous shells due to the transmission of the resultant forces of these impacts.

The effects of the impacts of individual meteorites have been observed in isolated localities such as Meteorite Crater, Arizona. In these localities, the result of the collision has been the formation of deep craters, in some of which have been found remains of the original meteorites. On account of the low thermal conductivity of the surface rocks, some of

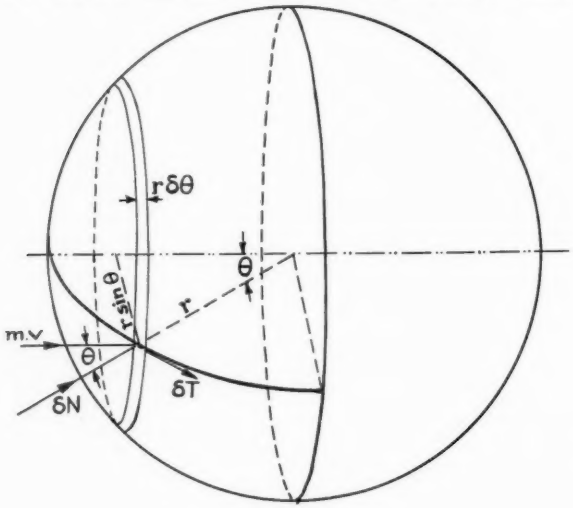


FIGURE 3

the material in the immediate vicinity of the point of impact and part of the meteorite appear to have been volatilized. Some of the energy of the colliding meteorite would have been absorbed by the resilience of the surrounding rocks, resulting in their temporary or permanent deformation. It would seem, therefore, that the effects to the surface of a continuous series of impacts over a large area would have been a steady disintegration of the exterior shell and a thinning of the crust.

In order to examine the consequences to the underlying material, let us consider the effects on an elemental ring of the crust such as that indicated in Figure 3. If θ is the angle between the normal to the surface and the direction of the impacts along the ring, the area of the ring will be:

$$\delta A = 2\pi \times r^2 \sin\theta \times \delta\theta. \tag{1}$$

With a mass of meteoritic material equal to μ, moving with a velocity v, striking in a unit of time a plane of unit area perpendicular to the direction of the swarm, the rate of change of momentum after impact in a unit area of the ring during the interval required to absorb the energy of the meteorites by the resilience of the crust would have been:

$$\mu \times v \times \cos\theta, \tag{2}$$

and the force on the ring due to the impacts:

$$2\pi \times m \times v \times r^2 \sin\theta \times \cos\theta \times \delta\theta, \tag{3}$$

where m is the equivalent mass of the meteoritic material affecting the underlying shells, after the necessary allowances are made for the dissipation of some of the energy through atmospheric resistance, conversion to heat energy at impact, *etc.* The normal and tangential components of this force are:

$$\delta N = 2\pi \times m \times v \times r^2 \sin\theta \times \cos^2\theta \times \delta\theta, \tag{4}$$

$$\delta T = 2\pi \times m \times v \times r^2 \sin^2\theta \times \cos\theta \times \delta\theta, \tag{5}$$

respectively. If the crust is assumed to have been elastic, within elastic limits,

$$T = 2\pi \times m \times v \times r^2 \int_0^{\theta} \sin^2\theta \times \cos\theta \times d\theta,$$

$$= \tfrac{2}{3}\pi \times m \times v \times r^2 \sin^3\theta.$$

With the crustal shells free to move over the underlying material, fracture would have occurred when

$$\tfrac{2}{3}\pi \times m \times v \times r^2 \sin^2\theta = 2\pi \times r \times \sin\theta \times h \times p,$$

where h = the thickness of the crustal shell, and
p = the ultimate stress in the shell,

i.e. when

$$\sin\theta = \sqrt{(3 \times h \times p)/(m \times v \times r)} \qquad \text{or}$$

$$\theta = \sin^{-1}\sqrt{(3 \times h \times p)/(m \times v \times r)}. \tag{7}$$

If, however, the underlying material had resisted sliding, an elemental block of the crust would have been subjected to forces such as those indicated in Figure 4, together with a pair of equal and opposite tensile forces acting upon, and the shear across, planes parallel to the paper.

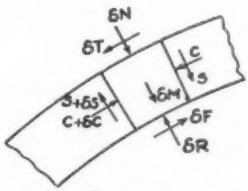


FIGURE 4

The effect of the couple caused by δT and δF would have tended to rotate the block in a counter-clockwise direction unless balanced by the internal shearing stresses S, and would have tended to open fissures at the surface. It appears, therefore, that there would have been a tendency for three regions to develop in the crust of the exposed hemisphere, as indicated in Figure 5, *viz.*:

i. Where the crustal shell remained intact in the form of a cap

whose semi-arc is given approximately by

$$\theta = \sin^{-1} \sqrt{(3 \times h \times p)/(m \times v \times r)}$$

of equation 7;

ii. A region where the external forces were sufficient to overcome the internal resistance, and to "peel" off the crust; and

iii. An intermediate band where the tangential forces fractured the surface, but the resistance between the shells was sufficient to prevent any considerable displacement of the fragments.

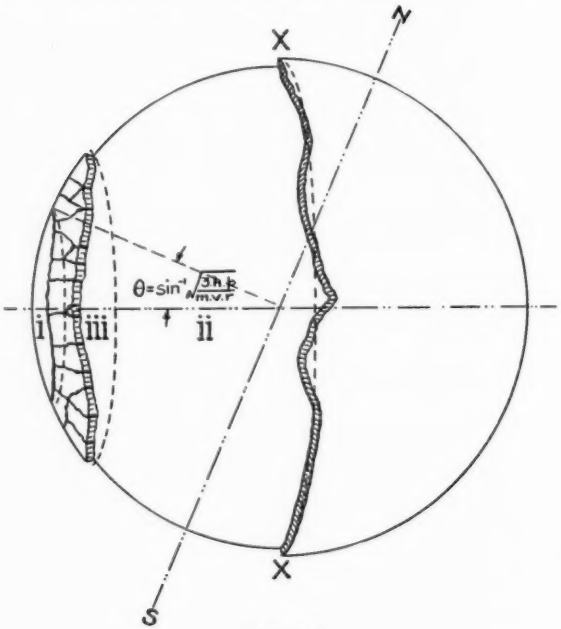


FIGURE 5

It will be convenient to refer to these regions (i), (ii), and (iii) as the "cap," the "Pacific region," and the "intermediate band," respectively.

Hitherto, only the "spatial" effects of the interception have been considered. In the time element, the consequences would have been:

1. A sudden effect on the crustal and upper vitreous shells, resulting in the thinning of the crust and the stripping of a section, together with the probable melting of some of the vitreous shell, and

2. A series of effects extending over a long period of time as a result of readjustments of equilibrium necessitated by the disturbances caused by the impacts.

From equation 2, the tangential component of the impacts per unit area, up to the time fracture occurred, would have been equal to

$$\tfrac{1}{2}m \times v \times \sin 2\theta,$$

and this would have been a maximum at points where $\theta = 45°$. It appears likely, therefore, that fracture would have commenced at points where the angle between the normal at the surface and the direction of the impacts was 45°. Once fracture had begun, in the region where $\theta > 45°$, the effect of the tangential component of the forces on the elemental ring would have been increased by the outward pressure of the fractured material within the ring, and there would have been a tendency for this material to be displaced towards the region indicated by the line XX in Figure 5, which will be referred to as the "Pacific margin." For points where $\theta < 45°$, there would have been a tendency for successive rings of crustal material to become fractured, displaced, and be moved outwards, where the tangential forces were sufficient to overcome the resistance of the underlying shells, as in the case of the other fractured material in the Pacific region. The intermediate band would have developed where this resistance was sufficient to balance the tangential forces and here, although fracture might have taken place, the crustal shell would not have suffered any considerable displacement in the initial stages of the bombardment. For points where

$$\sin\theta \not> \sqrt{(3 \times h \times p)/(m \times v \times r)},$$

the internal stresses appear to have been insufficient to cause fracturing, and here the crustal material would have remained intact in the form of a cap.

During an effective bombardment of about an hour, the earth's rotation would have exposed to the impacts of the meteorites a part of the hemisphere which had been sheltered at the commencement of the bombardment, and this portion of the crust, along the western side of the Pacific region, would have suffered in a manner similar to the rest of this area. The rotation would have turned the eastern side of the cap into the critical region of the intermediate band, and would have resulted in the "leading edge" of the cap's becoming fractured, while the eastern side of the intermediate band, originally maintained in place by the resistance offered by the underlying shells, would have been displaced outwards like the other crustal material in the Pacific region. The continuous stream of fresh meteorites during the successive stages of the bombardment would appear to have caused a steady thinning of the cap and the crustal material in the intermediate band maintained *in situ* by the resistance of the underlying material. During its displacement toward the Pacific margin the fractured material in the Pacific region would have been shattered and partly volatilized by these impacts. The relatively sudden removal of crustal material from the Pacific region, with the consequent changes in pressure on the underlying rocks, would have resulted probably in the partial melting of the vitreous shell, and this process might have occurred during the final stages of the bombardment. The cap would have been depressed probably under the pressure of the impacts into the underlying molten material, and this "cushioning" might have reduced the effects of shattering and thinning. While

the rest of the surface was being carried eastward by the earth's rotation, the pressure on the spherical surface, due to these impacts, would have been probably sufficient to displace the cap westward with relation to the Pacific margin, and nearer to the Asiatic side of the Pacific region, over the underlying material. With the melting of the material underlying the intermediate band, there would have been a tendency for the fractured crustal material to drift apart and away from the cap.

It appears possible to identify the Australian continent with this cap, with the Australian Bight the one-time leading edge. The depressing of the cap, with its subsequent rising after the bombardment had ceased, together with the westerly drift due to the earth's rotation, would account probably for the rotation of the continent, which would have brought the flattened edge to the south of the land mass. The fragments of the intermediate band, once the resistance of the underlying material had been reduced by the melting of the vitreous shell, would have tended to drift westwards and towards the equator, and might be identified with the East Indies. The average elevation of the Australian continent is about 340 meters and, with the exception of Europe, to which reference will be made later, it is the lowest of all the land masses. From considerations of isostasy, this low elevation would point to a thinner sial shell "floating" lower in the sima. From equation 7, the required radius of the hypothetical cap is approximately

$$\sqrt{(3 \times h \times p \times r)/(m \times v)}.$$

It is interesting to observe that, for a thickness of crust of 60 miles and an ultimate stress of 50 tons per square foot, assuming an equivalent mass m of 1/500th that of earth-material, moving with a velocity of 15 miles per second, this equation gives a diameter for the cap of approximately 2,400 miles, which agrees closely with the longer dimension of the Australian continent. The region occupied by the Pacific and Indian Oceans provides approximately the required area for the Pacific region.

It does not appear likely that the Pacific region will provide evidence of the bombardment by a marked difference in the chemical composition of its rocks, which appear similar to those occurring in the other oceans. Much of the material striking the sial shell would have been volatilized, while that falling in the Pacific region, on account of its greater density, would have sunk through the fractured material. This area was probably covered with a thin skin of sial débris, which would have modified the chemical composition of the rocks now forming the ocean basin. The presence of this extra-terrestrial material, however, may be found to provide an explanation for some of the magnetic peculiarities in this region.

It seems probable that some of the crustal sial, fractured during the bombardment, was depressed into the molten material underlying the Pacific margin and became wedged there. These sial fragments, with a density less than that of the sima into which they had been submerged,

by their tendency to rise and exert an upward pressure under the edge of the sial shell, might have contributed to a gradual upward movement of the crust along the Pacific margin. The lifting of the crustal edge would have tended to draw inward some of the sima along the margin of the land mass, and would have resulted in the occurrence along the Pacific margin of greater ocean depths such as the Atacama Pit and the Peru-Chile Basin and Trough. This movement, extending over a long period of time, would result in continual dislocations in the crustal material, and might account for the unstable earthquake region surrounding the Pacific Ocean. The instability of this region would be likely to produce conditions favorable for the injection of magma from below the crust through fractures in the weakened parts of the scarred edge, already overstrained by the original bombardment, and would probably result in extensive vulcanism. An apparently satisfactory explanation for the phenomenon of the volcanic girdle around the Pacific Ocean, peculiar to this region, seems thus to be suggested.

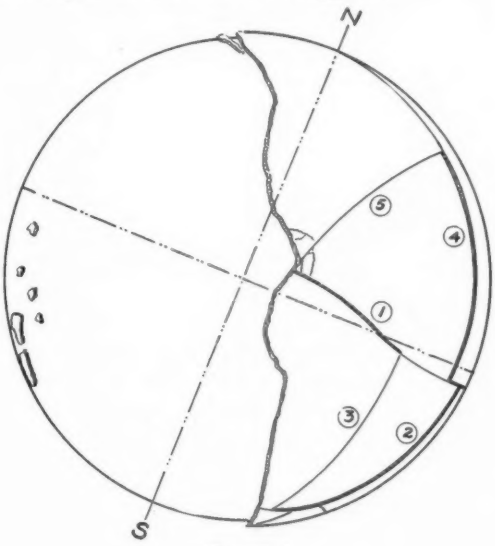


FIGURE 6

The changes in pressure and the melting of the underlying material in the Pacific region would have released the lighter elements, such as some of the gases, which had been absorbed within the lithosphere, and would have resulted in an alteration of the chemical composition of the underlying material, which might account for the marked difference between the sial and sima now. The release of these lighter elements, in addition to having resulted in a denser atmosphere, by the combination of free oxygen and hydrogen, might have increased the hydrosphere, which

would have accumulated in the basin of the Pacific region. The possible extension of the hydrosphere after Archaean times might have contributed to the differences in characteristics between some of the metamorphic rocks of the later systems and the Archaean types. Climate in other parts of the world would have been affected by changes in this region, and fluctuations in the levels of the ocean bed, involving successive flooding and receding of the seas over the continental areas, would have

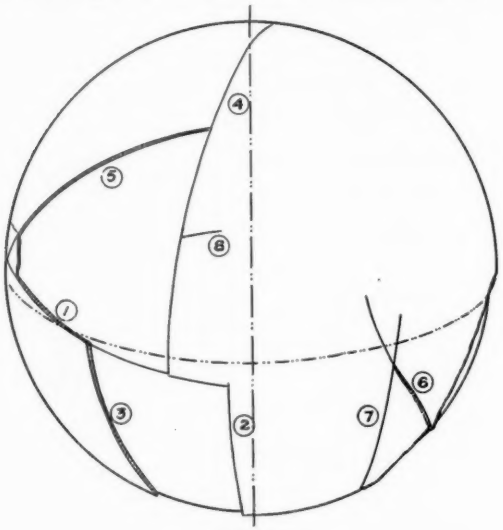


FIGURE 7

resulted probably in the alternating epi-continental and dry-land conditions observed in other regions. The extensive diastrophism which appears to have marked Pre-Cambrian times, resulting in effects to these rocks without parallel in the later systems, seems to point to some cataclysm that has never been repeated. Periodic readjustments of equilibrium consequent on an early upheaval in the earth's history, together with the adjustments required for isostatic compensation consequent on denudation and deposition, would appear to have been sufficient to cause the earth movements observed in the later systems.

The impacts due to the bombardment, compression along the Pacific margin, and changes in conditions below the sial shell, caused perhaps by the deep-seated convection currents which might have been set up by the "boiling" in the Pacific region consequent on the melting of the underlying material referred to previously, would have induced enormous strains in the crust of the hemisphere that had been sheltered from the effects of the meteorites' direct impacts. It seems probable that, under such strains, the crust would have fractured, possibly by shearing

in large circular arcs, such as those indicated in Figs. 6, 7, and 8, which enable the main land masses to be identified. The shearing of the crust along the fractures indicated by (1), (2), and (3), and (1), (4), and (5) might have resulted in the segments bounded by these fractures' being depressed into the underlying material. The thinning of the sial shell in these segments, perhaps by the melting or disintegration of the under surface, in order to maintain isostatic equilibrium, would have made these segments less resistant to subsequent straining, and would have led to their fracturing more quickly than the adjacent parts of the crust. The recovery of acid continental material from the bed of the Atlantic Ocean would seem to point to this region's having been once a land area, of which the West Indies, as the fragments of the Atlantic segments, might be perhaps some of the remains.

FIGURE 8

The known lithological and palaeontological characteristics of South America and Africa appear to be explained more satisfactorily by the postulation of the existence, at one time, of a South-Atlantic segment than by Wegener's hypothesis of continental drift. The melting of the material underlying the sial shell would have allowed some movement of the continental masses, as suggested by Wegener, under the relatively small forces due to the earth's rotation, tides, *etc.* This tendency for the land masses to drift towards the equator might have caused the separation of North America and Eurasia along the fracture (4), while a slight movement of the crust over the underlying material might account

for the wandering of the poles (*i.e.* the variation of latitude). The low elevation of the northern plains of both Eurasia and North America, as well as the fringe of islands off both northern coasts, which would have formed as fragments broke away from the northern edges of these continents, appears to be the result of the separation of these land masses. As the crust was drawn over the underlying material, there would have been a tendency to thin the sial shell and also to develop considerable tensile strains in the northern margins of these land masses. The extensive mountain-building which resulted in the east-west Alpine-Himalayan systems of Tertiary times might have been caused by the equatorial drift of Eurasia and the rolling-up of the Indian sub-continent along the fracture (6), while the much earlier Pre-Cambrian orogenic movements, which resulted in generally north-south systems, might have been due to the action of forces along the Pacific margin and changes under the sial shell. The great fault running through east Africa, the Red Sea, and the Jordan valley might be identified with this fracture (6), and an important secondary fracture (8) might have caused the development of the Mediterranean Sea. A movement of the Iberian peninsula, relative to the northwestern coast of Africa along this fracture (8), would appear to account for the peculiar folding of the Alps and Carpathian Mountains and might explain the occurrence of the deep basins in the Mediterranean Sea. Such a movement of the European continent, in addition to the thinning of the sial shell, which would have affected the elevation of the continent, to which reference has been made previously, might have caused, by weakening the crustal material, an unstable earthquake and volcanic region in the Mediterranean.

With the setting-in of glacial conditions in the Ice Ages, water would have been withdrawn from the hydrosphere and imprisoned in the ice-caps around the poles. The shrinking of the hydrosphere would have resulted in lowering the ocean level, and, by exposing a greater surface of the land masses, might have provided additional land bridges. The accumulation of heavy loads at the poles would have tended to depress the crust under the ice-caps. The local effect of these loads would have been the formation of a ridge outside the cap, while, over a period of time, it would appear that these masses of ice would have had a general effect upon the earth as a whole. As the crust was slowly depressed under the heavy loads of the ice-caps and the polar diameter was shortened, it would appear likely that the "flowing" of the underlying material, due to the heavy loads applied for a long period of time, would have resulted also in some increase of the equatorial diameter. These conditions would have increased the bulge of the earth, caused primarily by its rotation, and, by raising the levels of the lithosphere in some parts of the earth's surface with relation to sea-level, might have resulted in the emergence of more land areas. With the return of warmer conditions, causing the ice-caps to melt, the removal of the loads would have resulted in the crust's recoiling, and, as a consequence of the return of some of the

frozen water to the hydrosphere, the ocean level would have risen, once again submerging some of the land areas. The strains induced in the crust by the recoil as the loads were removed, might have been sufficient to cause the already weakened Atlantic segments to be overstressed, resulting in their final collapse, and this collapse, with the higher ocean level, might explain the rapid disappearance of the land bridges in Quaternary times.

There appears to be general agreement that the palaeontological characteristics on the two sides of the Atlantic require that land bridges should have existed until about Tertiary times. The wide distribution of heliolithic culture has offered many problems, and the similarity of human customs and other characteristics among races in widely separated localities appear to demand some means of communication such as would have been afforded by land bridges, which seem to have existed, at one time, more generally than at present. The two Atlantic segments would have provided the required connection between the land masses, while their break-up and final submergence would account for the breaks in continuity observed.

Some mention might be made, in passing, of the distribution of man. The absence of remains of sub-men on the American continents has afforded grounds for much speculation, and, to account for the comparatively recent appearance of man in this part of the world, it has been suggested that a Mongolian type might have migrated *via* the Bering Straits into America. The existence in Asia of a people possessing characteristics similar to those of the American Indian has been considered to support this suggestion. The widespread characteristics of the American Indian, found in tribes separated by considerable distances on both of the American continents, would appear to indicate a stabilization of these traits which might be accounted for by a long period of inbreeding. If, after the separation of the land masses had commenced, this type had developed in the region of the Atlantic segments from an Old World stock, both the absence of primitive types and the ultimate arrival, when circumstances made this possible, of a type with the characteristic traits, would be explained. The presence in Asia of a people with American-Indian traits might be explained by a migration from America into Asia.

Returning to the consideration of the effects of the collisions upon the crustal material, we observe that the normal component of the forces would have been greatest at the center of the cap. The effects of the normal forces upon the surface of the earth would have been to shatter, melt, and volatilize some of the crustal material, and project fragments in a direction normal to the surface. The tangential forces would have resulted in the fracturing of the crust and would have tended to displace the fractured material toward the Pacific margin where it would have tended to accumulate. Fresh streams of meteorites, striking these fragments continuously, would have tended to project the material accumu-

lated along the Pacific margin away from the earth in a direction tangential to the surface, and carry away with this mass a cloud of finer particles, gases, and meteoritic material. Velocities of impact, which may have been from 15 to 20 miles per second, of the meteoritic swarm would appear sufficient to have displaced this material with the necessary velocity of projection for it to have reached the moon's orbit, at the distance of which, outside the critical region in the field of the earth's gravitational attraction, it would have been possible for a solid body to form. If a thickness of 60 miles had been removed from the Pacific region, a sufficient volume of material to form the moon would appear to have been available. This material would have consisted mainly of sial with a density of about 2.7, with, perhaps, some of the vitreous shell. The effects of the collisions and the rapid passage through the atmosphere would have modified the physical properties of the crustal material, and it is probable that the characteristics of the projected material would have resembled those of the lighter acid volcanic rocks such as pumice. It is significant that recent research has indicated that the material composing parts of the moon's surface resembles this rock in some respects. The cloud of débris removed from the earth would have included some meteoritic material with perhaps a greater density than that of the surface rocks. The time-interval required for the débris to pass out of the critical region would appear to have been sufficient for the differences in densities to grade the fragments partially, and the heavier material, such as the accompanying meteorites, with, perhaps, the fragments of the tiny original satellites overwhelmed by the storm, might have formed the core of the moon. The average lunar density of about 3.3 seems to be consistent with the properties of the material which might have formed the moon, since, although the core might have a density in the neighborhood of perhaps 5 to 6, the density of the material forming the surface would be probably below 2.0.

The earth's gravitational effects would undoubtedly have caused considerable tides within the body of the moon if it was ever in a plastic state, but an examination of the surface appears to leave some doubt as to whether it was ever entirely plastic. The mass of débris from the earth would appear sufficient to have captured a number of stragglers from the meteoritic swarm, which, in time, might have fallen into the moon's surface. Under such conditions the directions of the impacts would have been normal, or nearly so, to the moon's surface, and the characteristic lunar craters might have been formed in this manner. These craters are more common in the lighter areas than in the so-called "seas" or *maria*, and this fact might indicate that the *maria* are those portions of the moon's surface that became, at one time, plastic or perhaps molten. Mountain ranges are rare upon the moon, and the position of the *Alps* and the *Apennines* on the margin of *Mare Imbrium* is suggestive that this area might be one of the regions formed by the earth's tidal effects on some of the material that had been in a plastic state.

Some features, such as the bright streaks or "rays" radiating from a few of the lunar craters (notably *Tycho* and *Copernicus*), might have been produced by strains in the surface material of the moon, similar to those which perhaps caused the fractures in the earth's crust indicated in Figs. 6-8.

The main mass of débris which left the earth's surface would have carried with it some material that had been projected with a velocity insufficient to carry it out of the critical region of the earth's gravitational attraction. A portion of this material would have fallen back upon the earth, but some of it might have had a velocity of projection sufficient to enable the particles to describe orbits around the earth. Being still within the critical region, these particles would have been unable to coalesce into a single solid body, and would have remained in the form of a ring of discrete particles, similar to the rings of the planet Saturn. The sun's light, falling upon this ring, would be reflected, and, as seen from the earth, would appear as a lens-shaped glow visible in the east before sunrise and in the west after sunset. That the zodiacal light and the gegenschein are due to this ring seems not improbable.

The relative sizes of the earth and moon are so exceptional in the solar system that it does not seem possible to ascribe the origin of the moon to a cause similar to those which resulted in the births of the satellites of the other planets. Mars has two tiny attendants and Venus none so far as we know, yet the moon compares in size with some satellites of the Jovian planets, which are many times as large as the earth. It would seem that, as in the cases of the other members of the sun's family, the earth did at one time possess one or more tiny attendants which were overwhelmed by the meteoritic storm which struck their primary and which now may be part of the larger satellite. Mars at a greater distance from the sun would have had a better chance to escape such a cataclysm, but the peculiarities observed in connection with Venus might yet be ascribed to such a cause. The sun's gravitational effects are greater than the earth's upon the moon, and yet the mass of Venus is only about 0.8 that of the earth, while the ratio of the distances from Venus and the earth, where the solar gravitational attraction is equal to the attraction of the planet, is about ⅔. It therefore appears very probable that, had Venus suffered in the same way as the earth might have, the débris from Venus would have come under the sun's gravitational control. The relative sizes and densities of Mercury and the moon are interesting, and Mercury might eventually be identified as Venus' lost satellite. In this connection the peculiarities of Mercury's motion might be significant.

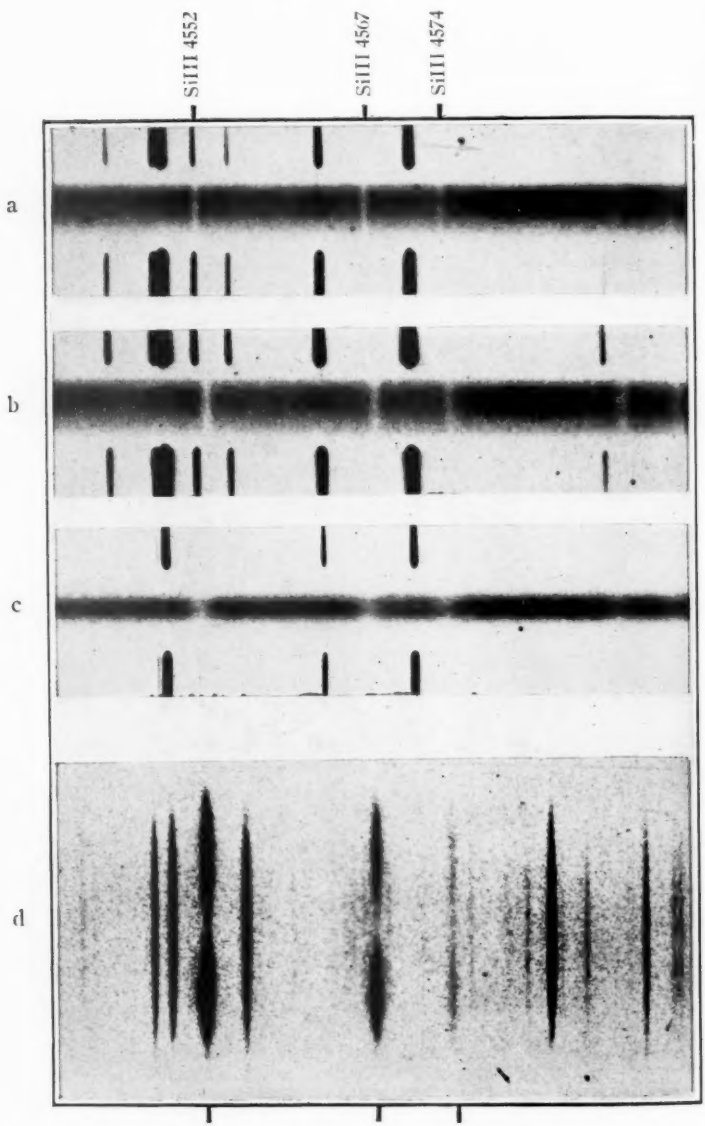
The appearance of Mars seems to indicate that this planet did escape a cataclysm such as that which may once have befallen the earth. The reddish areas on the Martian surface, where land conditions apparently exist, may be part of the original crustal material which, as in the case of the earth at one time, extended over the whole surface. It seems probable that this material resembles the sial over the vitreous shell of

Archaean times on the earth. The comparison of the appearance of Mars' surface features with Figs. 6, 7, and 8 is suggestive of an explanation of some of the markings on that planet. On account of the absence of an area on Mars such as the Pacific region on the earth, strains in the Martian crust would have tended to develop in it smaller but more numerous fractures or faults than those which might have occurred on the earth where the Pacific region would have tended to release the strains in the sial shell to some extent. It seems possible to identify these faults with the so-called "canals" which occur in large arcs on the surface of Mars. It appears probable that when the crustal material fractured, the underlying material was forced up between the adjacent parts of the crust and so produced gigantic dykes. Since the underlying material would have a density probably greater than that of the adjoining crustal sections, it might not have reached the elevation of the surface but might have formed a floor between the walls of the crustal sections, and thus provided a channel by which the melting caps in the polar regions are able to influence other regions on the surface of the planet. This flow along the "canals" would be probably the cause of the seasonal variations observed in connection with some of these features, as has been suggested by some authorities. Where the faults intersected, there would have been probably a tendency for the crust to founder at these points, and this foundering might have produced features similar to the *Syrtis Major* and other markings. Under these conditions subsequent faulting through these regions would have produced the effects of the "canals' " running through these areas, which is what is observed in some instances. The phenomenon of doubling observed in the case of some "canals" may be due to the occurrence of double faulting. If there were a difference in level between the floors of the two faults it would depend upon the quantity of flow from the poles whether one or both of the "canals" would be utilized, and upon this circumstance would depend whether a single or a double "canal" would be seen.

The apparent absence of a satisfactory theory to account for the earth-moon system, and the stalemated condition which the continental-drift hypothesis seems to have reached, have led the writer to attempt the development of the present treatise. The writer is not directly engaged in work in any of the fields with which this hypothesis is concerned, and is, on that account, not so reluctant as he might otherwise be, to venture on a line of argument which may be due for considerable criticism. It is hoped, that, however imperfect this hypothesis may be, the suggestions herein outlined may serve as a basis for discussion, out of which some much-needed theory may be developed. In conclusion, the writer wishes to express his acknowledgment to the many friends who, knowingly and unknowingly, have furnished him with suggestions and material for this paper. He hopes that the time will come when these persons may be mentioned by name without danger of embarrassment to any of them.

CEYLON TECHNICAL COLLEGE, COLOMBO, CEYLON

PLATE XIII



THE EFFECT OF STELLAR ROTATION.

a: γ Pegasi; b: β Canis Majoris; c: κ Orionis;
d: Spark of iron and silicon.

The Observation and Interpretation of Stellar Absorption Lines

By OTTO STRUVE

(Continued from page 451.)

VI. Stellar Rotation

In many stars, especially those of early type, all lines are broad and diffuse. In order to investigate this type of broadening we must, first of all, ascertain whether or not it is due to a peculiar, hitherto not recognized, form of the absorption coefficient. For this purpose we have selected three lines of Si III λλ 4552, 4567, and 4574. Plate XIII shows three stellar spectra. In γ Pegasi the lines are sharp and narrow; in β Canis Majoris they are appreciably broader, while in κ Orionis they are exceedingly broad. At the bottom the laboratory lines of Si III are shown together with some iron lines. The profiles for several plates of each star are shown in Fig. 11.

The theoretical multiplet intensities are

$$N_{4552} : N_{4567} : N_{4574} = 5 : 3 : 1$$

and give the relative numbers of atoms which are effective in producing these lines. If the absorption coefficient accounts for the shallow lines (ε Orionis) as well as for the narrow lines (γ Pegasi) the total absorptions should be in different ratios. When the line is shallow σNHf must be small over the entire extent of the line. Hence (26) must apply and

$$A = I_0 \int_{-\infty}^{+\infty} (1-1)\,d\lambda = I_0 \int_{-\infty}^{+\infty} \sigma N H f\,d\lambda = I_0 N H f \int_{-\infty}^{+\infty} \sigma\,d\lambda. \qquad (27)$$

The total absorptions are proportional to NHf and must be in the ratio

$$5 : 3 : 1.$$

For narrow lines the profiles are deep in the center and A will be related to NHf by an expression of the form of (6) or (14). Since γ Pegasi is a dwarf and has no turbulence, and since the total absorptions are of the order of 1 or 2A, which is ten times greater than the critical value of 0.1 A where the thermal curve of growth is flat, we are justified in expecting that for γ Pegasi the total absorptions will be in the ratio

$$\sqrt{5} : \sqrt{3} : 1 = 2.24 : 1.73 : 1.00.$$

The observations show conclusively that for all stars the ratios are $\sqrt{5} : \sqrt{3} : 1$. This holds for ε Orionis as well as for γ Pegasi. We conclude that the absorption coefficient has nothing to do with the broadening of the lines. The effect must be due to the superposition of lines which individually follow relation (6).

The broadening of the lines can be measured, and allowance can be made for different total intensities. It turns out that this broadening is proportional to the wave-length. This reminds us of the Doppler effect

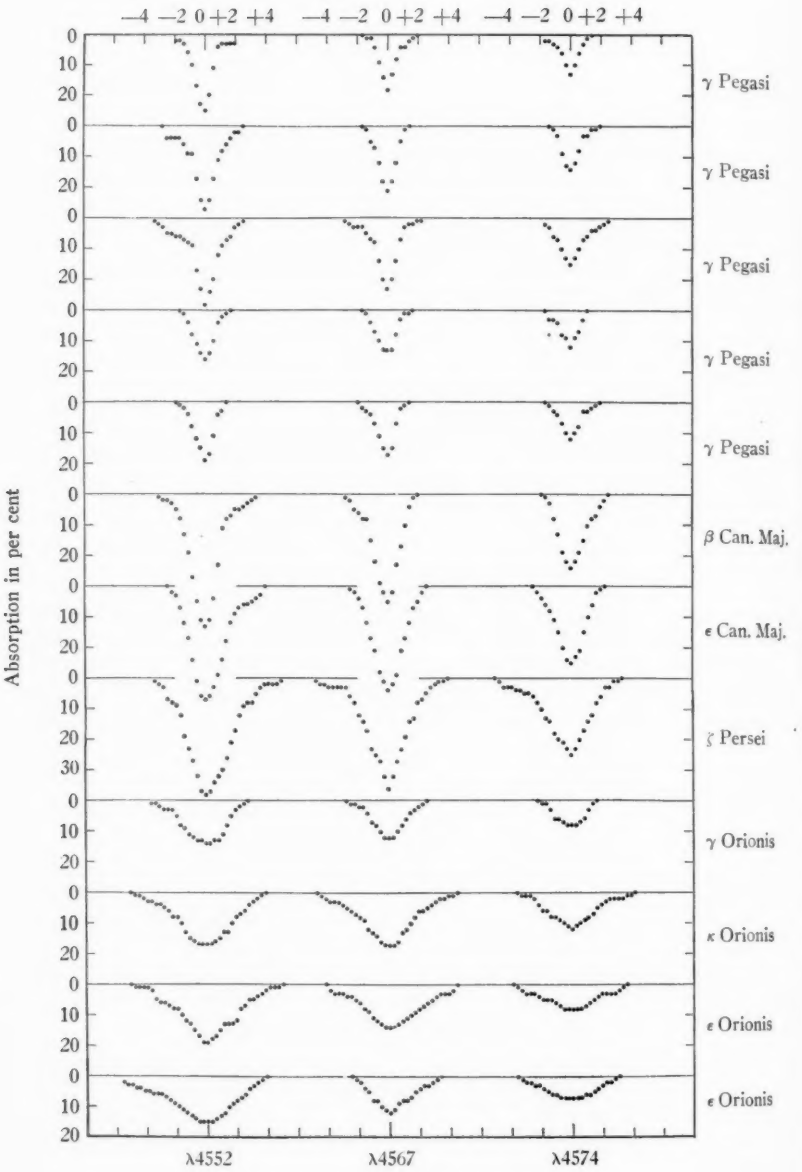


FIGURE 11

Profiles of Si III lines λλ 4552, 4567, 4572.

γ Pegasi has normal lines. In κ Orionis and ε Orionis the rotational broadening is very large.

$$\Delta\lambda = v\lambda/c, \tag{28}$$

and suggests that the broadening is due to superposition of lines displaced by radial motion.

An investigation of spectroscopic binaries shows that in all true binaries of short period and of large amplitude in the velocity curve the lines are exceedingly broad and diffuse. Since in close double stars we expect equality of orbital period and period of axial rotation of each component, we infer that the broadening is caused by axial rotation. In specific cases, where during a partial eclipse the rotational velocity can be measured by the method of Rossiter and McLaughlin, the agreement between v computed from (28) and the Rossiter-McLaughlin result is excellent.

The evidence has been carefully scrutinized, and there appears now no reasonable doubt that the diffuse spectral lines in such stars as ϵ Orionis, Altair, α Virginis, etc., are caused by axial rotation.

In the process of deriving the equatorial rotational velocity of a star it is not advisable to depend upon the line width $\Delta\lambda$ in (28). Instead it is necessary to produce an integration. We assume that we know the profile of the undisturbed line. In practice it is permissible to use the profile of the same line in a star of similar spectral type and absolute magnitude. Let this profile be given by

$$I = \psi(\Delta\lambda). \tag{29}$$

We now consider the line shifted by Doppler effect so that

$$I' = \psi(\Delta\lambda \pm v\lambda/c). \tag{30}$$

Finally, we integrate I′ over the entire disc of the star. The result is the profile of the broadened line.

$$I_{rot.} = \iint \psi(\Delta\lambda \pm v\lambda/c)\, dx\, dy. \tag{31}$$

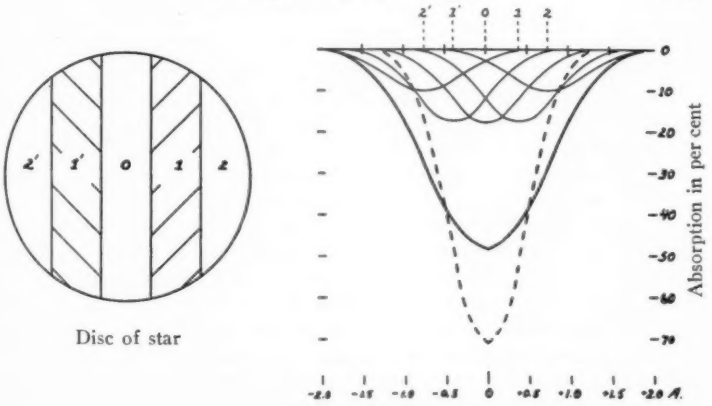


FIGURE 12

Construction of a Rotational Profile.

The dotted curve is the assumed normal profile. The summation of the separate curves labeled 2′, 1′, 0, 1, 2 leads to the rotational profile.

In this integration we must remember that v is a function of x and y, and that it has its maximum value, $v_{rot.}$, when $y = o$, $x = r$. The integration is readily carried out by graphical means, provided ψ and $v_{rot.}$ are known. We usually adopt a number of different values of $v_{rot.}$ and construct the profiles $I_{rot.}$ for each. We then compare these theoretical profiles with the observed profile and interpolate the correct value of $v_{rot.}$. Fig. 12 illustrates the integration. It is useful to remember, in this connection, that the component of the rotational velocity in the line of sight is constant for constant x. Hence it is sufficient to divide the apparent disc of the star into a number of vertical strips and to sum a number of displaced normal profiles each of which has been multiplied by the area of the corresponding strip.

A different and more elegant method for determining $v_{rot.}$ from the profiles, without knowledge of $\psi(\Delta\lambda)$ has been developed by Carroll. The method takes advantage of the fact that the curve $I_{rot.}$ contains certain properties which are due only to the process of rotational broadening and not to the initial form of $\psi(\Delta\lambda)$. The isolation of these properties is accomplished by Carroll by means of solving an integral equation. The result is $v_{rot.}$ and the original profile $\psi(\Delta\lambda)$. The method gives, in practice, similar results to the process used by Elvey and me.

The observed values of $v_{rot.}$ range from zero to about 250 km/sec. Large rotational velocities are frequent in classes O, B, and A. Within each class there is a real dispersion in the velocities after the effect of the inclination has been removed. This can be done statistically. For example, for B stars Miss Westgate finds:

$v_{rot.}$	0 - 50	50 - 100	100 - 150	150 - 200	200 - 250 km/sec.
% of stars	27	53	15	4	1

VII. Absorption Lines in Outer Shells

The rotational interpretation of the broad absorption lines in such stars as Altair and ϵ Orionis is so well established that the simultaneous occurrence of sharp and broad lines in the spectra of certain peculiar stellar spectra excites our interest. These stars usually have broad rotational lines of He I, sharp absorption lines of Fe II, Ni II, and sometimes other elements, while the hydrogen lines show sharp, very deep, but not perfectly narrow absorption cores, flanked by weak emission lines, which, in turn, are flanked by broad, diffuse wings suggestive of Stark effect. The H cores have typical turbulence profiles. But neither they, nor the sharp lines of Fe II, show any appreciable rotation.

Had these stars been more frequent they would have played havoc with our hypothesis of stellar rotation. But since they are rare and peculiar, in the sense that their spectra are often variable, I believe we can place full confidence in the rotational interpretation of their broad He I lines.

Furthermore, it is resaonable to suppose that the sharp cores of H and the faint emission lines occur in outer nebulous shells. We infer, then, that the shells do not rotate as solid bodies with the reversing layers, for

if they did, their portions which are projected upon the star's discs would show exactly the same rotational profiles as do the lines of He I.

Plate XIV shows the spectrum of a typical representative of this group—ζ Tauri. It is a spectroscopic binary discovered at the Yerkes Observatory by Frost and Adams. Orbits have been published by Adams and by Miss Losh. The period is 133 days and the range in radial velocity is small. It is probable that orbital motion alone cannot explain the peculiar variations in the velocity curves.

But for our purpose the most interesting feature of ζ Tauri is the fact that while other He I lines observable in the ordinary photographic region of the spectrum are broad and diffuse, the relatively inconspicuous line He I 3965 is exceedingly sharp and narrow.

The simultaneous occurrence of narrow and broad lines of a single element in a single stage of the atom is indeed unique. Perhaps we should now be seriously tempted to abandon the rotational hypothesis. But I still believe that the evidence in favor of it is so overwhelming that I am more inclined to look for another explanation. Perhaps, we may reason, the sharp He I line originates in the outer shell, while the broad He I lines are produced in the reversing layer. But if so, why does this particular line and no other originate in the shell?

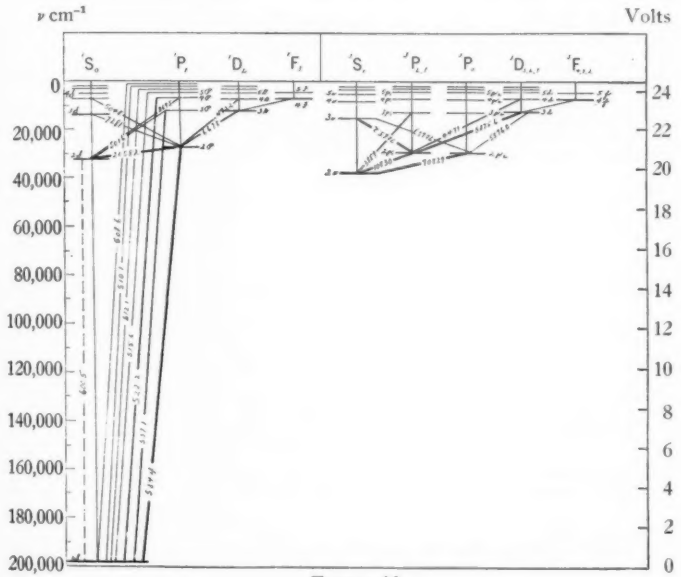


FIGURE 13

Grotrian Diagram for He I.
The singlet level 2^1S and the triplet level 2^3S are metastable.
(The wave-length λ 3695 should read λ 3965.)

The answer must be found in the metastability of the lower level, 2^1S, from which the line λ 3965 originates (see Fig. 13). By the rules of spectroscopy an S term cannot combine with another S term. This would violate the selection rule for the azimuthal quantum number, which states that the azimuthal quantum number must change by ± 1 in every transition. An S term can combine only with a P term. But the 2^1S term lies lower than any other term of the singlet system of He I except 1^1S. It cannot combine with the ground state 1^1S. Nor can it combine with any of the triplet levels, since inter-system combinations in He I are also forbidden.

If the metastability of state 2^1S explains the anomaly we should expect that other lines of the same series ($2^1S - n^1P$) would also be sharp. Unfortunately, the only other line accessible to our spectrograph is λ 5015, but it lies in the green part of the spectrum where the plates are not very sensitive. Our plate does not show this line. But other evidence leads me to believe that it will be found to behave exactly as λ 3965.

The explanation which I should like to suggest is the following: for some as yet undefined reason the shell contains an excess of atoms in state 2^1S, rendering all lines originating from this state relatively much stronger than we should normally expect.

In order to illustrate this phenomenon it may be well to consider, at first, a simple experiment. The various spectroscopic states of an atom correspond to different energy contents of the atom. When an atom is in state 2^1S it has stored up a certain amount of energy. If this atom absorbs the line λ 3965 it still further increases its energy content. Every time an atom swallows a quantum of light of the right frequency it increases its energy content. Without absorptions the atom would permanently remain in the state of lowest possible energy, 1^1S. (We ignore here the effects of collisions.) After each process of swallowing a dose of energy the atom remains for a short interval of time in the higher energy state. While it is in this state it can swallow another bite of energy and go to a still higher energy state. Or, if no quantum comes along soon enough it spontaneously, or under the influence of the field of radiation, discharges its excess energy returning to a lower state.

Perhaps it will be convenient to consider the atoms as balls arranged in a shallow trough at the bottom of an inclined surface. For the light quanta we shall substitute projectiles of shot which are directed as a more or less steady stream against the balls by a group of children at some distance from the inclined surface. Some of the balls will be hit by the projectiles and will be forced to run up on the inclined surface. After a short interval they will come back to the trough and be available once more as targets. The game consists of finding out how many balls are, at any given moment, on the inclined surface.

Suppose we designate the number of balls found at any given moment in the trough by N_1 and the number of balls on the inclined board by

N_2. Then $N_1 + N_2$ is known: it is the total number of balls with which we started our game. Suppose, for example, that $N_1 + N_2 = 100{,}000$.

Further, let the frequency of hits be such that in one second one-tenth of the balls in the trough are hit. Accordingly, in one second $.1N_1$ balls start their journey up the incline.

Next suppose we watch with a stop-watch the length of times it takes for a single ball to return to the trough after it has been hit. Let this interval of time be 0.1 second. Then in one second $10\,N_2$ balls will come back into the trough.

Now, if the game has been going on for some time, there will be what we call a steady state. The numbers in the trough and on the board will be practically constant. Hence the number leaving the trough in one second must be equal to the number returning in one second:

$$0.1N_1 = 10N_2.$$

Combining this with

$$N_1 + N_2 = 100{,}000$$

we can solve for N_1 and N_2:

$$N_1 = 99{,}010 \qquad N_2 = 990.$$

So far the game has been rather trivial and no intelligent child would ever take any interest in it.

But now suppose that the inclined board has a second incline which diverts a fraction of the balls into a separate trough, from which they cannot run back into the first trough, although they are open to being hit by the projectiles. What are the relative populations N_1, N_2, N_3? We recognize the "metastability" of the second trough! Suppose that each ball remains 0.1 sec. on the incline, as before, and that, on the average, one out of every five balls runs into trough two. Then we have the following three equations:

$$N_1 + N_2 + N_3 = 100{,}000 \qquad .1N_1 = 8N_2 \qquad .1N_2 = 2N_2$$

Solving these, we find

$$N_1 = 79{,}208 \qquad N_2 = 990 \qquad N_3 = 19{,}802 \qquad (32)$$

The number of balls in the "metastable" trough is exactly one quarter of the number in the original "ground-level" trough.

Suppose we now reduce the stream of projectiles in such a manner that in one second only 0.01 of the total available balls gets hit. In the astronomical analogy this would correspond to a decrease in the density of the light quanta which pervade the gas. Such a decrease could, for example, take place, if the radiating source, the star, were placed at a correspondingly greater distance from the gaseous shell.

We now have to solve new equations. For the case of two troughs we find

$$N_1 + N_2 + N_3 = 100{,}000 \qquad 0.01N_1 = 8N_2 \qquad 0.01N_2 = 2N_2$$

Solving these we obtain

$$N_1 = 79{,}920 \qquad N_2 = 100 \qquad N_3 = 19{,}980 \qquad (33)$$

The interesting thing about solutions (32) and (33) is that the number of balls in the normal "high-energy" level N_2 has changed from 990

to 100—almost in proportion to the density of projectiles. But the number in the "metastable" level, N_3, has changed hardly at all. It still bears the same ratio, ¼, to the number in trough one, N_1.

The "metastability" of state three is important. If there were a passage between the two troughs which would permit some of the balls to run from trough two to trough one the population N_3 would be greatly reduced and would be approximately proportional to the density of the projectiles. It is quite easy to modify the equations so that they will represent this case and we shall not take the time to prove the proposition.

Our experiment is exactly analogous to the case of a gaseous shell illuminated from a distance by a star. If the distance is small, as in the reversing layer, the population in a normal excited level of He I, for example 2^1P, will be fairly large. If the distance is great, say ten times greater than for a normal reversing layer, the quanta are reduced in density by about one hundred. The population in state 2^1P will also be reduced by about 100, and all lines originating from that state will be correspondingly weakened. But the population in the metastable level 2^1S will be practically the same in both cases.

Hence, our interpretation accounts not for the *strength* of λ 3965 in the shell, but for the *relative weakness* of other lines, such as λλ 4009, 4144, 4388, etc., in the shell. Since we are only able to compare line intensities among themselves, we are, of course, not in a position to say whether λ 3965 is exceptionally strong or the other lines exceptionally weak.

The problem becomes even more exciting if we consider also the system of triplet lines in He I. Barring collisions, which are probably infrequent in tenuous outer shells of stars, a triplet level can be populated only after the He I atoms have been ionized. There are practically no line transitions between the two systems and the state 2^3S is metastable.

The problem can be completely solved in a manner, originally due to Rosseland, which is in principle identical with our game of balls. This task has been recently performed by Dr. Wurm and myself and the results give the populations of the various states in the two systems of He I for different degrees of the dilution of the radiation and for different temperatures.

We already know that by means of the curve of growth we can determine from the observed total absorption of a line the population of the lower energy level. For example, if the values of A are proportional to NHf we should be able to form the following relation

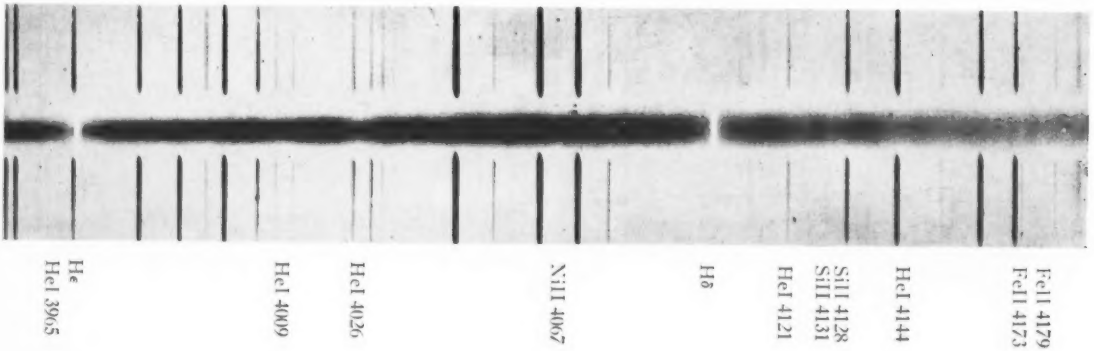
$$\frac{\text{A 3965 shell}}{\text{A 3965 rev. layer}} \times \frac{\text{A 4009 rev. layer}}{\text{A 4009 shell}} = \frac{N_3 \text{ shell}}{N_3 \text{ rev. layer}} \times \frac{N_2 \text{ rev.}}{N_2 \text{ shell}} \qquad (34)$$

Now, by the above discussion

$$N_3 \text{ shell} = N_3 \text{ rev. layer} \qquad N_2 \text{ shell} = W \times N_2 \text{ rev. layer} \qquad (35)$$

W is the "dilution factor" which measures, in effect, the relative density of the quanta in the shell and in the reversing layer. Combining (34)

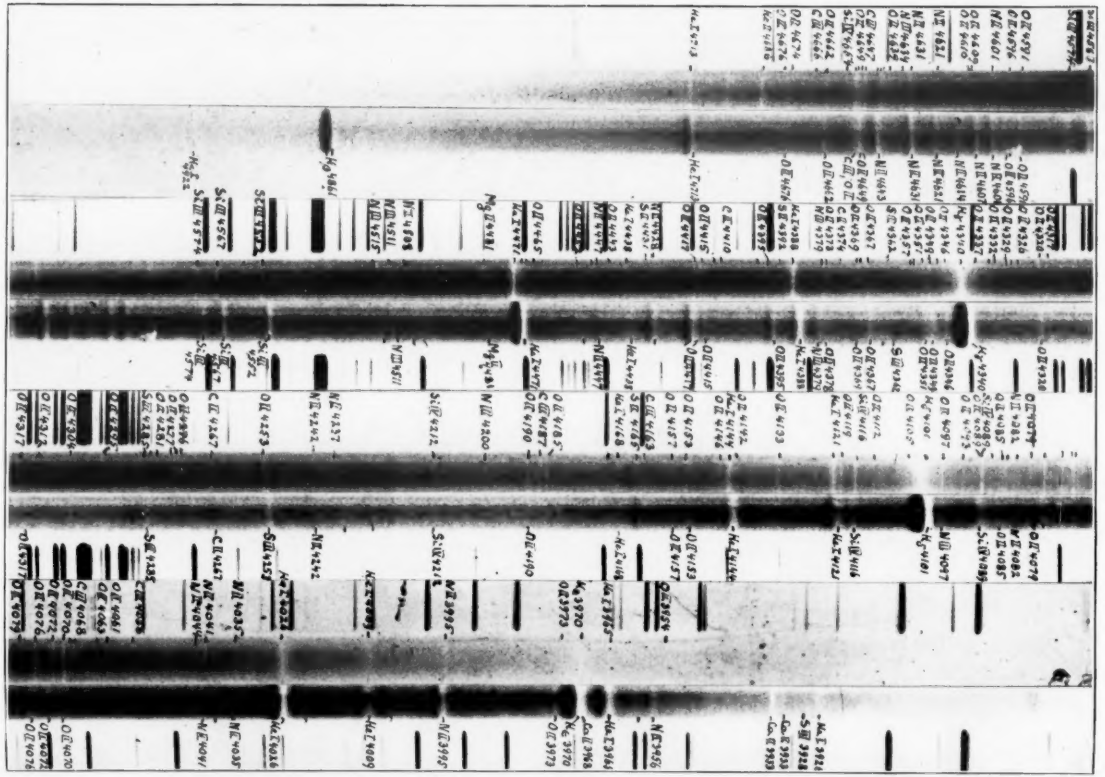
PLATE XIV



THE SPECTRUM OF ζ TAURI.

The HeI line λ3965 is sharp and narrow, while the other lines of HeI are very broad and diffuse.

PLATE XV

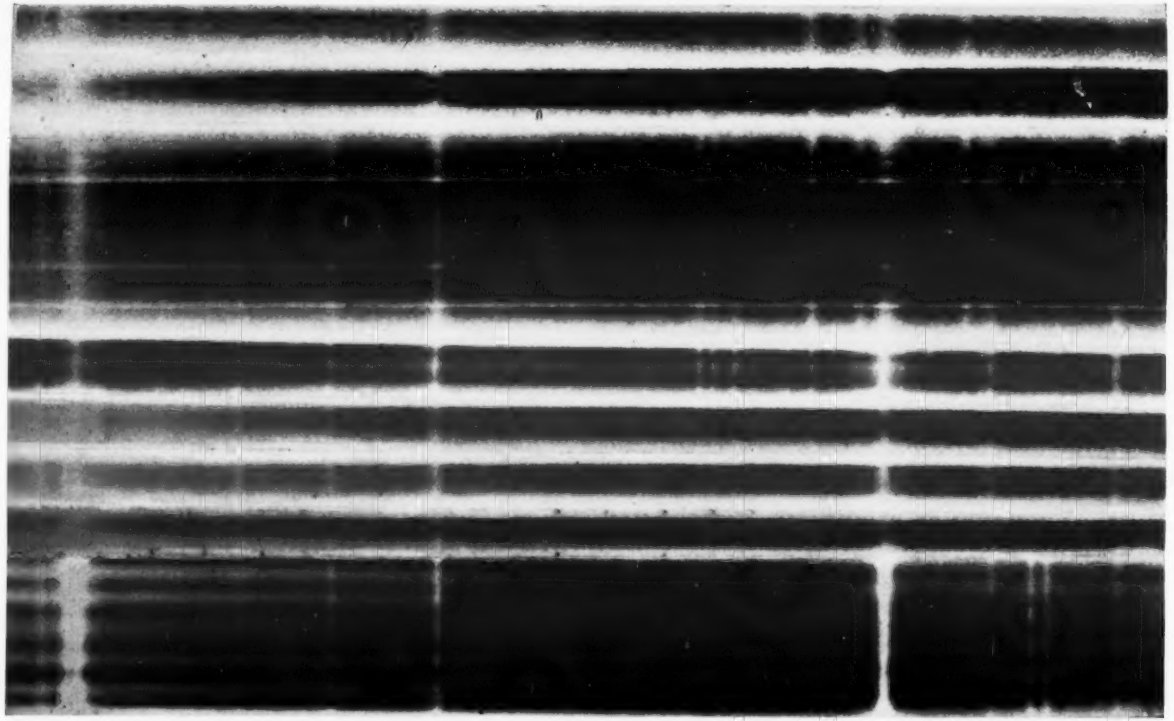


a: the spectrum of P Cygni; b: the spectrum of τ Scorpii

PLATE XVI

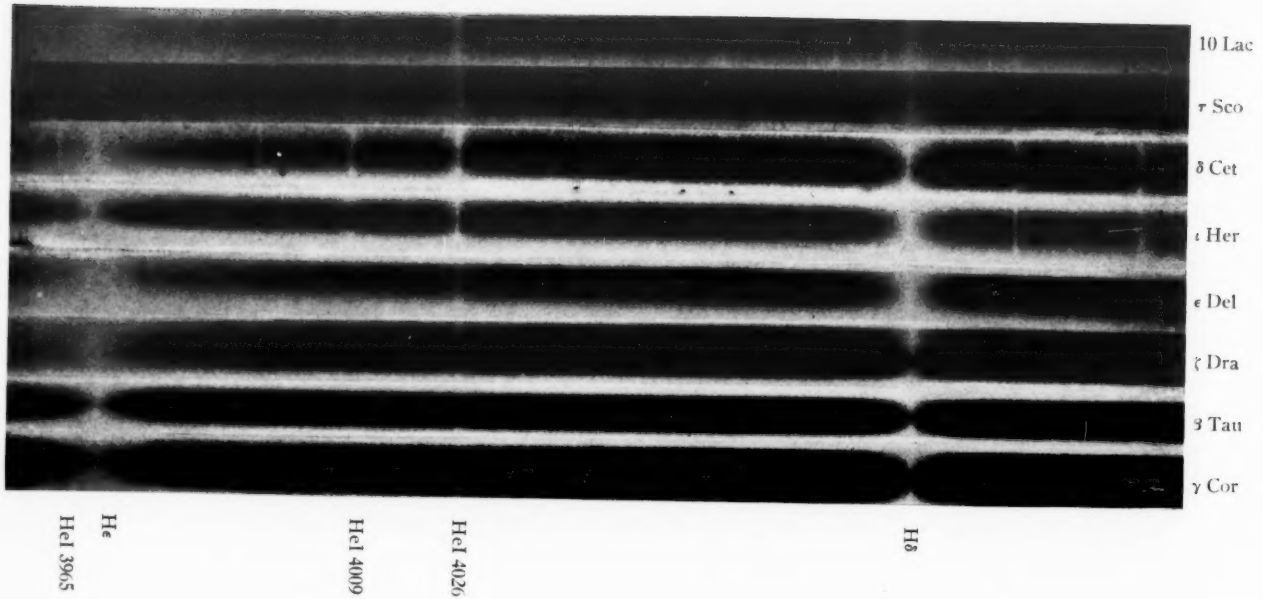
a : the spectrum of P Cygni ; b : the spectrum of τ Scorpii

PLATE XVI



SEQUENCE OF B-TYPE GIANTS.

PLATE XVII



SEQUENCE OF B-TYPE DWARFS.

and (35) we obtain an equation for W.

The observations of ζ Tauri are not sufficient to obtain a solution for W. But evidence from several other shells leads to the approximate result

$$W = 0.01 \tag{36}$$

This is not exact, but it does give us the correct order of magnitude for the dilution factor.

The dilution factor is, by definition, equal to one when the radiation comes uniformly from all directions. If the star, of radius R_1 is at a certain distance r from the gas, W is the solid angle subtended by the star at the gas, divided by 4π. This is equal to

$$W = \tfrac{1}{2}(\sqrt{1 - R^2/r^2} - 1) \tag{37}$$

and this is very nearly

$$W = R^2/4r^2 \tag{38}$$

Substituting (38) in (36) we find that the radius of the shell is roughly five times larger than the radius of the star.

These results indicate quite clearly that the problem of the excitation of lines by diluted stellar radiation is of great importance in astrophysics. We are already able to explain several interesting phenomena. For example, it has long been a puzzle why the spectra of shells frequently show Fe II in absorption, but rarely Mg II 4481, although in ordinary stellar reversing layers the latter is always present when Fe II is excited, and in the A stars is always much stronger than Fe II. The answer is that all observable lines of Fe II start from metastable levels, while Mg II 4481 has a lower level which, by two successive downward transitions, connects with the ground state of Mg II.

The spectrum of ζ Tauri (Plate XIV) shows a fairly strong, narrow line at λ 4067 which must be identical with Ni II. This line is present in normal A type stars, but it never occurs in normal early type B stars. Even in the A type stars it is relatively less conspicuous. From our discussion of He I and Fe II we are led to conclude that the lower level of this line is metastable. An inspection of the spectroscopic data shows that this is actually the case.

VIII. Departures from Thermodynamic Equilibrium in Stellar Atmospheres

All the spectrographic phenomena discussed in the preceding section may be classed together under the heading: departures from thermodynamic equilibrium. Such departures are, of course, extreme in the gases in interstellar space. Dunham has shown that for interstellar titanium only those lines are visible which originate from the lowest member of the multiple ground level. For all higher levels the dilution factor renders the population negligible. The extreme character of the effect in interstellar space renders it difficult for investigation. In the shells the departures from thermodynamic equilibrium are much less extreme, and are therefore more susceptible to study.

The fact that these departures in the shells have not before been recognized is largely due to the fact that for many elements the distribution of atoms in higher levels simulates a normal Boltzmann distribution. In thermodynamic equilibrium the population in any state is given by

$$n_2 = n_1 g_2 e^{-\chi_2/kT}/g_1, \tag{39}$$

where χ_2 is the energy of the state, k is the Boltzmann constant, T is the temperature, and g_1 and g_2 are the statistical weights.

For a normal (not metastable) level excited by diluted radiation we have approximately

$$n_2 = n_1 W g_2 e^{-\chi_2/kT}/g_1, \tag{40}$$

while for a metastable level, we have, with fair precision

$$n_3 = n_1 g_3 e^{-\chi_3/kT}/g_1. \tag{41}$$

When an element possesses only lines originating from normal excited levels, the factor W ill affect all populations in the same degree. It will be difficult to distinguish such a distribution from a normal Boltzmann distribution. Similarly, if all lines, like in Fe II, originate from metastable levels, the distribution will be that given by the Boltzmann principle. The second type of elements will be stronger than the former, but this may escape attention, being masked by differences in the abundance of the various elements. Only in elements in which lines from metastable and from normal levels simultaneously produce observable lines will we be able to discover large differences caused by W.

This explains why the spectra of some typical shells closely resemble the spectra of normal stars. 17 Leporis (Plate VIII) is a good example. It is surrounded by an expanding shell which gives rise to most of the observable lines. Most of these are normal in relative intensity, and we have already used them for our discussion of turbulence. But Mg II 4481 is absent from the spectrum of the shell. A broad and diffuse line due to Mg II comes only from the deeper reversing layer.

Another example is P Cygni (Plate XV) which bears a striking resemblance to τ Scorpii, a normal dwarf of type B0. But, again, Mg II 4481 is weak in the shell of P Cygni. The He I lines clearly reveal the anomaly discussed in the preceding section, and there are some other more or less conspicuous anomalies which stamp the spectrum of P Cygni as peculiar. But within a single atom, such as O II, the departures from thermodynamic equilibrium are quite small.

The possibilities for further research which are opened up by our application of Rosseland's theory of cycles are almost without limit. Thermodynamic equilibrium places a stamp of similarity upon the spectra. With the removal from the strict uniformity imposed by Boltzmann's principle we find an infinite variety of spectra. Every atom must be studied individually, and every line intensity must be evaluated with the help of the transition probabilities, the energy difference, and the

dilution constant. The transition probabilities are known for only a few atoms and not much progress can be made in the theory until these data have become available. But the observational work can proceed without delay. We require accurate total absorptions for as many shells as are available. Fortunately, this number is by no means small. Several have been investigated by Merrill and McLaughlin, while others are recorded in the literature.

The interpretation of the He I anomaly in outer shells suggests that similar anomalies might exist in normal supergiant or even in dwarf spectra of class B. This is, indeed, the case. The He I anomaly in the B stars has been a puzzle for many years, although I have recently suggested an explanation which is quite similar to that developed for the shells in Section VII.

Plates XVI and XVII show sequences of B type supergiants and dwarfs. Of particular interest are the lines of He I:

λ 4026 ($2^3P - 5^3D$) λ 4009 ($2^1P - 7^1D$) λ 3965 ($2^1S - 4^1P$)

The triplet line is strong throughout both sequences. The singlet line λ 3965 is apparently strong throughout the sequence of supergiants. In the dwarfs it is relatively weak, except near the maximum of intensity of He I (δ Ceti and ι Herculis). The singlet line λ 4009 is interesting. In intermediate types it is rather strong, both in giants and in dwarfs. In the giants it fades out rapidly toward the hotter stars (α Camelop. and λ Orionis) but remains quite strong in the cooler stars. In the dwarfs λ 4009 also fades out towards hotter stars, although not as completely as it does in the giants. The line is also weak in the cooler dwarfs.

The phenomena are here not as simple as in the shells. For one thing, we have large Stark effect and collisional damping for λ 4009 and λ 4026 in the dwarfs. In the giants all lines are subject to large turbulence-broadening. These factors all play an important role, as does also the difference in the radiation damping constant γ which by virtue of the strong downward transitions toward state 1^1S is much larger for the singlets than for the triplets. This effect has been pointed out by Unsöld, who has remarked that when a line is broad and shallow because of excessive Stark effect and small NHf, the total absorption is practically independent of γ. On the other hand, when NHf is large and the line falls upon the $\sqrt{\text{NHf}}$ branch, the total absorption depends upon γ. The interplay of these factors renders an interpretation of the curves of growth rather difficult.

Nevertheless, there is a rather striking difference, noted also for $\lambda\lambda$ 4387 and 4472, in the behavior of the singlets and triplets. This is essentially similar to the behavior of the same lines in the shells and is caused by the fact that the 2^3S level is metastable.

It is not surprising that in giant atmospheres the dilution is still sufficiently large to cause anomalies in the intensities of He I. The dwarfs

must perhaps be considered as normal, the fading of λ 4009 being attributed to the curve of growth. However, λ 4009 rarely, if ever, reaches saturation and is therefore probably always on the steep part of the curve of growth; λ 4026 may approach saturation near type B2.

I have made no attempt to deal with this problem in detail since Dr. Menzel has informed me that Mr. Goldberg is investigating the matter at Harvard.

IX. The Sequence of Stellar Atmospheres

The atmosphere of a normal dwarf star like the sun consists of a thin layer of gas, several hundred kilometers in thickness, which gives rise to the absorption lines. In a normal red giant the reversing layer must be about 2000 times higher than in a dwarf. This would be of the order of 10^6 km.

In ζ Aurigae we have direct observational evidence of an absorbing atmosphere which has a height of roughly one astronomical unit, or 1.5×10^8 km. In ε Aurigae the height of the atmosphere is at least 2.6×10^8 km. A similar height has also been found for VV Cephei.

In the B-stars surrounded by shells we have determined the radius of the shell in terms of the radius of the star. The radii of the stars are not known. However, if we use Russell's approximate formula based upon absolute magnitude and color index, we find, as a crude estimate, about 30 times the radius of the sun, or 2×10^7 km. This would make the radius of the shell about 10^8 km—a value which is of the same order as the radii of the atmospheres of ζ Aurigae and ε Aurigae.

This suggests that there is no intrinsic difference between the two types of atmospheres. Evidently, we must begin to think of the shells of stars as enormously extended atmospheres. These atmospheres often show evidence of stratification, as in P Cygni, where the lines corresponding to the lowest ionization energies are produced at the greatest distance from the center of the star. The outer atmospheres do not rotate as solid bodies with the stars. Sometimes they are expanding (P Cygni, 17 Lacertae, β Lyrae), but more often they are in a somewhat unstable equilibrium. This equilibrium is constantly upset by small-scale turbulence. However, most shells are also subject to violent changes. These are more fully described in the communication of Dr. McLaughlin.* It is of interest that the outer atmosphere of ζ Aurigae also appears to undergo large variations.

The origin of the shells is not known. Nor have we any clue as to the reason why some B stars possess shells while others do not. Great luminosity seems to favor the formation of a shell, but not all supergiants have shells. The problem is obviously similar to that of ordinary Be stars. They are somewhat more luminous than the average, but the correlation is by no means perfect.

Some years ago I pointed out an interesting correlation between the widths of the emission lines in Be stars and the rotational velocities de-

*Popular Astronomy, XLVI, 361, 1938.

termined from the absorption lines. More recently Merrill has found that the broad lined stars have, on the average, stronger emission lines than the sharp lined stars. Both results suggest that rotation has something to do with the origin of the shells. But not all rapidly rotating stars possess shells (α Virginis), and so far we have found no physical difference between rapidly rotating stars which have shells and those which do not.

But these difficulties will doubtless be overcome before very long. The progress in the interpretation of stellar absorption lines within the past fourteen years has been so imposing that we need have no fear for the future. The immediate problem is to elucidate the structure and stratification of the shells by means of their absorption lines. It will then be possible to relate the results to those on the emission lines in Be stars. Finally, an attempt should be made to apply the theory of excitation of lines by diluted radiation to the novae.

In this paper I have used a number of illustrations which had originally been prepared by some of my colleagues at the Yerkes Observatory, and I take this opportunity to express to them my thanks for the use of this material.

YERKES OBSERVATORY, MAY, 1938.

Jupiter X and XI

By PAUL HERGET

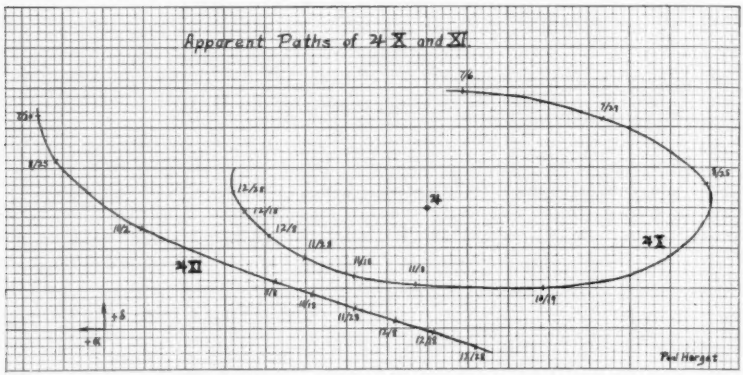
The discovery by Dr. Seth B. Nicholson of two new satellites of Jupiter was reported briefly in these pages (p. 474) in October. A sufficient number of observations are now available to compute fairly reliable orbits for these new objects. The results in both cases produce very striking and remarkable coincidences.

The solution of this problem is complicated by several circumstances. The Sun, which is usually taken as the origin of coördinates in the solar system, is relegated to the position of a disturbing body, and Jupiter is used as the origin about which the motion takes place. But in the Jovicentric system, the Sun has a mass of 1047.35 and we are not justified in assuming in advance that it will not produce very large disturbances, so that it is necessary to solve a problem involving three bodies, namely, the satellite, Jupiter, and the Sun. Also, from the observed direction of motion it is impossible to tell whether the object is revolving in a clockwise direction on one side of Jupiter or in a counterclockwise direction on the other side, so that there are two mathematical solutions. Since only one can be real, it becomes necessary to discriminate between the two results, usually on the basis of subsequent observations. Finally, since the object is so very far away, the orbit is very sensitive to slight deviations from the true positions, as a small change in the apparent direction of the object corresponds to a large actual shift in space at such great distances.

For Jupiter X, the observations of July 6, July 27, and August 25 were used and the resulting adopted elements are shown below. For comparison, the elements of Jupiter VI and Jupiter VII are also shown, and it will be immediately apparent that the three orbits are a set of almost identical triplets. With almost equal inclinations, and nodes nearly sixty degrees apart, the three orbits are situated in space like three interlocking links of a chain, but with each link interlocked with both of the other two.

	X	VI	VII
Inclination	28°.27	28°.44	27°.75
Node	82.51	143.99	204.63
Eccentricity	0.13244	0.158	0.207
Semi-major axis	0.0786	0.0767	0.0785
Period in days	260.5	250.57	259.65

(The elements of Jupiter VI and VII are taken from the papers of Bobone.)



The observations of July 30, August 25, and October 2 were used for Jupiter XI. These elements are given with those of Jupiter VIII and Jupiter IX for comparison, and again there is a close resemblance among these elements. The orbits are of greater eccentricity and also form a triply-interlocking group, even though the mean distances are not so nearly coincident. The retrograde motion of XI is more nearly in the plane of the ecliptic than the previously known retrograde orbits of VIII and IX.

	XI	VIII	IX
Inclination	163°.38	147°	155°
Node	231.75	332	0
Eccentricity	0.20678	0.378	0.222
Semi-major axis	0.1508	0.1572	0.1602
Period in days	692.5	739	758

(The elements of Jupiter VIII and IX are taken from a paper by Nicholson.)

It seems very remarkable that, when one sets out, as Dr. Nicholson did, to examine the region about Jupiter with our most powerful telescope with discovery of satellites the avowed objective, both resulting objects should "join up" with the only two known pairs in Jupiter's satellite system, and thereby form triplets. It is a great tribute to Dr. Nich-

olson's observing skill that his efforts should have been rewarded by not only one, but two discoveries, but the future may show that he has done more than just discover two more moons of Jupiter. The implications of these discoveries on the current theories of the origin of the solar system remain to be explored. It is highly improbable that VI, VII, and X are such closely resembling triplets merely by chance. And does some underlying cause also control the presence of the triplet of VIII, IX, and XI? This discovery now renders the well-known "capture theory" much more highly improbable as a means of explaining the retrograde motions of these objects. Can it be that VI, VII, and X are a miniature analogue of the interlocking minor planets which revolve about the Sun? And does the group of VIII, IX, and XI at the outermost bounds of Jupiter's system suggest an analogy which we have not yet discovered in the solar system, namely, orbits of much larger eccentricities and inclinations on the outermost periphery of the system? The orbit of Pluto confirms the tendency which this speculation indicates. Time and the opportunity to digest these newly discovered bits of knowledge may greatly alter the current scientific opinion concerning these questions.

CINCINNATI OBSERVATORY, CINCINNATI, OHIO, OCTOBER, 1938.

Planet Notes for December, 1938

By R. S. ZUG

NOTE: Greenwich Civil Time is employed, unless otherwise stated. To obtain Eastern Standard Time subtract 5 hours, Central Standard Time, 6 hours, etc. The planetary phenomena are described as they are to be seen from latitude 45° N. The data are taken chiefly from the *American Ephemeris and Nautical Almanac*.

Sun. The positions of the sun, for December 1 and December 31, respectively, are: $\alpha = 16^h\,25^m.5$, $\delta = -21°\,40'.2$; $\alpha = 18^h\,37^m.7$, $\delta = -23°\,9'.7$. The apparent motion of the sun is in the main eastward during December. The month begins with the sun in the constellation Ophiuchus, which constellation it entered November 29. On December 17 the sun enters the constellation Sagittarius, and its eastward motion continues through this constellation for the duration of the month. Winter begins December 22, $12^h\,14^m$, which is the instant the sun reaches the winter solstice. The declination of the sun at the solstice is $-23°\,26'\,39''$, the southernmost declination of the year. Values for the equation of time are as follows:

Date 1938	Equation of Time (Mean - Apparent) m s	Date 1938	Equation of Time (Mean - Apparent) m s
Dec. 2	−10 53	Dec. 18	− 3 49
6	− 9 19	22	− 1 50
10	− 7 35	26	+ 0 10
14	− 5 45	30	+ 2 8

Moon. Phenomena of the moon will occur as follows:

		h m
Full Moon	Dec. 7	10 22
Last Quarter	14	1 17

		h	m
New Moon	Dec. 21	18	7
First Quarter	29	22	53
Perigee	9	1	
Apogee	24	19	

Mercury. December 1 finds Mercury an evening star, six days past greatest eastern elongation. It is poorly placed for observation, due to its location near the southern portion of the ecliptic. Inferior conjunction is reached December 14.

Venus. Venus passed inferior conjunction with the sun November 20, and it should be possible to locate the planet as a morning star by December 1, in the southeastern heavens just before sunrise. The brilliancy of the planet increases rapidly after December 1, the stellar magnitude reaching a maximum of —4.4 on December 26.

Mars. Mars is a conspicuous morning star during December. On December 1 it will be located in the constellation Virgo, about 3° north of the star α Virginis (Spica). During the month it moves eastward about one hour of right ascension, and into the constellation Libra. The stellar magnitude is +1.8.

Jupiter. Jupiter moves slowly eastward through the constellations Capricornus and Aquarius during December. The elongation from the sun, however, is gradually diminishing. The stellar magnitude of the planet is now about —1.8. Planetary observers report that exceptionally fine detail is now discernible on the Jovian disk.

Attention is called to the item on p. 474 of the October issue of POPULAR ASTRONOMY concerning the splendid discovery of two additional satellites of Jupiter, X and XI, by Dr. Seth B. Nicholson of the Mt. Wilson Observatory. The new satellites are difficult objects of the 19th magnitude, and were discovered by means of photographs taken with the 100-inch reflector.

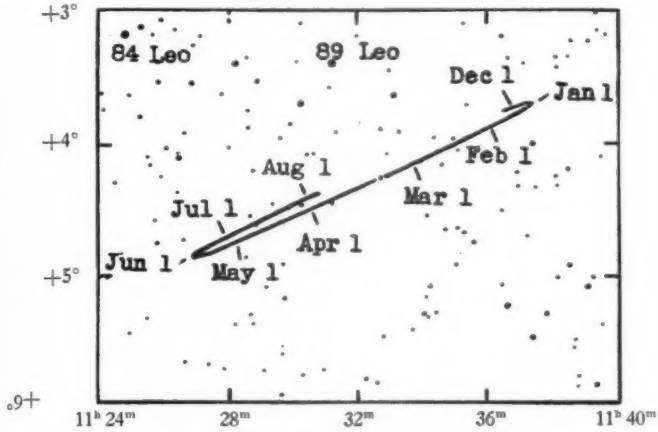
Preliminary orbits have now been computed for Jupiter X by Dr. Paul Herget of the Cincinnati Observatory, by Dr. R. H. Wilson, Jr., of Mt. Wilson, and by Miss Persis E. Fall and Miss Roxie White at the Students' Observatory of the University of California at Berkeley. The orbits obtained are in good agreement and indicate that the period of revolution of Jupiter X about its primary is of the order of 260 days. The semi-major axis of the orbit is about 7¼ million miles in length. This, together with a value of 0.135 for the excentricity (an average from the different orbits), would indicate that the distance of X from Jupiter varies from a maximum of 8¼ million miles to a minimum of 6¼ million miles. It is interesting to note that the period of Jupiter X is practically the same as that of Jupiter VII, and not much different from that of Jupiter VI. The eighth and ninth satellites of Jupiter have been estimated to be 25 miles in diameter. On this basis and assuming the same albedo, the newly discovered satellites, both of which are a magnitude fainter than Jupiter VIII and Jupiter IX according to the discovery announcement, may be very small objects perhaps only 5 miles in diameter!

Saturn. Saturn remains near the southern boundary of the constellation Pisces during December. It is in slow retrograde motion until December 15, after which the motion is direct. The ellipse defining the apparent angular dimensions of the ring system now has a major axis of approximately 42″ and a minor axis of 6″. The planet is becoming a more favorable object for early evening observation with the advancing season.

Uranus. Uranus is to be found in the constellation Aries, the following being the positions for December 1 and January 1, respectively: $\alpha = 2^h\ 50^m.3$, $\delta = +15°\ 57'.4$; $\alpha = 2^h\ 46^m.7$, $\delta = +15°\ 42'.3$. An occultation of Uranus will occur

on December 5 (see "Occultation Predictions," in this issue).

Neptune. In order to aid observers in locating the planet Neptune, the accompanying chart has been prepared. The star background has been copied from the B.D. (Bonn Durchmusterung) star maps, and the path of Neptune superimposed, allowance being made for precession. The drawing illustrates the path of Nep-



THE PATH OF NEPTUNE AMONG THE STARS, FROM DECEMBER, 1938, TO AUGUST, 1939.

tune from December 1, 1938, to August 1, 1939, the position of Neptune being indicated for the first of each month within this interval. The smallest dots represent stars of from 9.5 to 10 magnitude. Two stars 84 (τ) Leonis, magn. 5.2, and 89 Leonis, magn. 5.8, which are present on fairly detailed star charts such as *Norton's*, are shown on the chart.

It is noted that Neptune passes close to four B.D. stars during its course this year. The planet comes a few minutes of arc from B.D.+4°2505 on February 15. On March 11 it passes close to B.D.+4°2498, and on March 25 it passes close to B.D.+4°2496. The planet will pass close to B.D.+4°2492 April 3 while it is retrograding, and again July 30 when its motion is direct. There are thus a number of occasions when micrometric measures can be made between Neptune and fundamental reference stars.

Asteroid Notes

By HUGH S. RICE

The large minor planet Ceres is the asteroid best located for observation during this period by users of small telescopes. At this time, it is still retrograding at the Taurus-Aries-Cetus boundary. On the evening of November 9, it is about 1° northeast of the star ξ Tauri, and from there it moves to a position on December 15, about 1°.5 north of λ Ceti. The average magnitude is 7.4. If these positions be marked on a star chart, the object can be picked up without the aid of a special diagram. It does not go back to the direct motion until in January.

The Astronomisches Rechen-Institut recognizes the following new names of

asteroids, as named by Boyer at the Observatoire d'Alger-Bouzaréah: 1392 Pierre, 1400 Tirela, 1412 Lagrula, 1413 Roucarie, 1414 Jérôme, 1415 Malautra, 1416 Renauxa.

Hayden Planetarium, American Museum of Natural History,
New York, October 20, 1938.

Occultation Predictions

(Taken from the *American Ephemeris*)

Date 1938		Star	Mag.	Immersion: Greenwich C.T.	Immersion: *a*	Immersion: *b*	Immersion: Angle E from N	Emersion: Greenwich C.T.	Emersion: *a*	Emersion: *b*	Emersion: Angle E from N
				h m	m	m	°	h m	m	m	°
Occultations Visible in Longitude +72° 30′, Latitude +42° 30′.											
Dec.	4	29 Ari	6.1	23 4.9	−1.2	+1.2	93	0 8.6	−0.9	+2.2	225
	6	26 B.Tau	6.4	0 28.5	−1.7	+0.1	118	1 19.7	−0.7	+3.0	210
	9	74 B.Gem	6.2	2 27.5	−1.2	−0.8	141	3 12.6	−0.7	+2.9	226
	9	110 B.Gem	6.2	10 3.9	−1.0	−1.0	88	11 2.9	−0.3	−2.0	304
	11	a^2 Cnc	5.7	1 37.2	+0.2	+0.8	104	2 31.0	−0.1	+0.9	280
	11	60 Cnc	5.7	5 47.8	−1.5	+1.2	87	6 55.6	−1.4	−1.0	313
	13	55 Leo	6.0	12 33.1	−0.2	−3.4	175	13 11.4	−2.0	−0.1	240
	14	431 B.Leo	6.2	5 54.1	−0.4	+1.6	85	6 48.7	−0.4	−0.5	322
	29	λ Psc	4.6	0 48.7	−1.6	−1.8	103	1 47.9	−0.6	+1.2	207
Occultations Visible in Longitude +91° 0′, Latitude +40° 0′.											
Dec.	3	δ Psc	4.6	0 31.4	..	..	125	1 7.3	..	..	178
	4	29 Ari	6.1	22 48.5	−0.4	+1.5	78	23 49.7	−0.6	+1.8	241
	5	Uranus	6.0	9 55.9	+0.3	−2.4	129	10 33.9	−0.2	+0.4	218
	5	124 B.Ari	6.4	9 59.3	−0.2	−0.2	55	10 46.3	+0.4	−1.6	292
	6	26 B.Tau	6.4	0 5.7	−0.7	+1.0	100	1 1.9	−0.5	+2.2	227
	9	74 B.Gem	6.2	2 12.2	−0.6	0.0	131	2 57.5	−0.2	+2.3	233
	9	110 B.Gem	6.2	9 45.2	−1.3	−1.5	115	10 54.5	−1.2	−1.3	277
	10	BD+14°1850	6.4	14 0.0	−0.1	−1.6	120	14 53.6	0.0	−1.3	278
	11	60 Cnc	5.7	5 25.6	−0.8	+1.0	97	6 31.7	−1.1	+0.1	295
	15	χ Vir	4.8	11 21.1	−2.5	+1.8	73	12 16.6	−0.6	−2.3	345
	19	β^1 Sco	2.9	11 18.5	..	..	37	11 43.5	..	..	352
	29	λ Psc	4.6	0 13.2	−2.2	−0.4	88	1 29.5	−1.1	+1.3	215
Occultations Visible in Longitude +120° 0′, Latitude +36° 0′.											
Dec.	2	δ Psc	4.6	23 37.9	−0.8	+1.3	90	0 39.4	−0.6	+2.3	219
	5	124 B.Ari	6.4	9 45.8	−0.9	−1.0	89	10 50.5	−0.6	−0.7	256
	5	26 B.Tau	6.4	23 56.8	+0.3	+1.2	81	0 48.5	+0.1	+1.4	250
	8	64 Ori	5.2	11 31.6	−1.8	+0.3	62	12 24.6	−0.4	−2.8	321
	9	110 B.Gem	6.2	9 12.3	..	..	161	9 54.7	..	..	224
	10	30 B.Cnc	6.1	12 50.3	−2.4	+0.6	62	13 36.4	−0.2	−3.4	343
	10	BD+14°1850	6.4	14 3.7	+0.2	−3.7	169	14 39.3	−1.8	+0.4	235
	11	60 Cnc	5.7	5 13.4	+0.1	+0.8	98	6 8.3	−0.3	+0.6	287
	11	κ Cnc	5.1	11 29.5	−2.0	−0.5	104	12 47.3	−1.5	−1.8	308
	12	14 Sex	6.3	13 36.8	−1.7	−1.2	115	14 53.9	−1.4	−1.8	303
	15	χ Vir	4.8	10 40.8	−0.5	+0.1	123	11 48.5	−1.0	+0.4	289
	28	6 G.Psc	6.2	1 1.3	..	..	116	1 50.5	..	..	182
	28	λ Psc	4.6	23 10.4	−1.5	+2.0	53	0 37.3	−2.0	+1.2	245

The quantities in the columns *a* and *b* are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result in degrees, taking the signs into account, by the quantity under *a* for the star to be observed; similarly,

with the latitude, using b; apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

Comet Notes

By G. VAN BIESBROECK

No known comets are under observation at the present time. Several faint periodic comets are expected next year but none will be in reach before the end of this year. Amateurs having a good clear horizon should not neglect to sweep the sky for unexpected cometary visitors which can surprise us any time. The best opportunity for such discoveries is in the evening sky shortly after sunset as well as in the morning sky before dawn.

Williams Bay, Wisconsin, October 21, 1938.

METEORS AND METEORITES

Meteor Notes from the American Meteor Society

By CHARLES P. OLIVIER, President

Despite the moonlight, which so effectively ruins any meteor display, many scores of persons observed the Perseids and sent in their results. As these reports are still coming, it would be premature to attempt even a brief résumé. Conclusions will be given when more data are at hand. However, a number of brilliant fireballs were reported for the middle of August, and it is hoped that the heights of some can be computed. Any reader who has an observation on any of these is begged to send it in, as it might add just what is most needed. The fall showers will be more favorable as to moonlight. In October, last quarter will fall on the 16th, and the maximum of the Orionids is due October 19, or occasionally a day or two later. Observations on any date in the second half of October have special interest. Will not our numerous inactive observers make a *real* effort to observe several times in this interval? Last quarter falls next on November 14, just a day or two before Leonid maximum. Also the mean is near the radiant, but nevertheless conditions will be fairly good and observations should be made from November 14 to 18, inclusive, for that important stream. There is no real hope of again seeing the Bielids, which would normally be due a few days later.

The main part of these Notes consists of an article by one of our oldest members in point of service, R. A. McIntosh, now the best known meteor observer in the Southern Hemisphere. In regard to the general question of meteor frequencies, so highly developed by Hoffmeister, we see that McIntosh's results seem in general confirmatory. However, a very interesting article appeared in *A.N.* Nr. 6326, written about a year ago by J. Hoppe of Jena Observatory, replied to by Hoffmeister in *A.N.* Nr. 6353, in which he goes most critically into the validity of the method, basing his remarks upon the large number of variables involved, some of which are difficult or as yet impossible to evaluate with any certainty. I am thinking of reviewing this article later, but mention it here as what is to follow would come under its criticism of the general method. Yet as Hoffmeister's results seem to be independently confirmed, at least in part, by velocities directly determined

elsewhere, McIntosh's paper should be publishd as a further confirmation. In fact, the physical theory of what actually happens to meteors penetrating our atmosphere is at present wholly incomplete, or perhaps the juster remark would be there is no general agreement among men who should be authorities on the subject. Personally, I do not believe enough accurate data as yet exist by which to test theories with the thoroughness that is desirable. Disagreement is hence to be expected.

Flower Observatory, Upper Darby, Pennsylvania, 1938 August 31.

Meteor Rates in the Southern Hemisphere*

By R. A. McINTOSH F.R.A.S.

The determination of meteor rates for each day of the year may at first glance seem to be a compilation of data interesting only to the meteor observer. Such data, however, are of fundamental importance in meteoric astronomy, providing a clue to the velocities of meteors, and therefore answering the question whether they belong to our solar system or come from interstellar space.

Schiaparelli made the first theoretical investigation of meteor rates in 1866,[1] and his work was followed by papers by von Niessl[2] and De Tillo.[3] During the present century Dr. C. Hoffmeister[4] has carried the subject further, deriving a complicated mathematical formula in which there are three variables—the frequency of the meteors, their velocity, and the altitude of the meteoric apex. As the altitude of the apex can be determined, once the frequency curve has been found, the velocity can be calculated. As a result of his investigations Hoffmeister was able to show that the sporadic meteors not definitely associated with comets were travelling with hyperbolic velocity and consequently coming to us from outside the solar system.

The belief in the great preponderance of hyperbolic velocities among meteors which had gradually been forced upon meteoric astronomers from theoretical considerations has recently received interesting observational confirmation from the results of the Harvard Arizona Meteor Expedition (1931-33),[5] where, by means of an ingenious rocking-mirror device, a marked preponderance of hyperbolic velocities was found in all but the principal meteor showers.

The lack of reliable observations of meteor frequencies in the southern hemisphere has often been deplored by contemporaries in the northern hemisphere. The work performed in New Zealand in the past seventeen years is therefore of considerable value. The Meteor Section of the New Zealand Astronomical Society has not only pioneered meteoric research in this hemisphere but also is the only body actively conducting such observations at the present time.

One fact has been evident for some time—that in this hemisphere we enjoy a higher average rate of meteoric activity than is found in the northern hemisphere.

*Read before Section A (Mathematics and Physics) of the Australian and New Zealand Association for the Advancement of Science, Auckland, January, 1937.

[1] Entwurf einer Astronomischen Theorie der Sternschnuppen.

[2] *Astr. Nach.*, **93**, 209, 1878.

[3] *Bull. Astr.*, **5**, 237 and 283, 1885.

[4] *Astron. Abhandlungen*, Band 4, nr. 5; Veröffentlichungen der Universitätssternwarte . . . Band ix, heft i; Das Interstellare System der Kleinkorper, Berlin, 1936.

[5] *H.C.O. Circular* 391.

My own meteoric observations were begun in 1919, and since the formation of the meteor section in 1927 I have enjoyed the assistance of several other observers. During this period 935½ hours have been spent in meteoric observations, no less than 13,000 meteors having been recorded. The average rate is therefore 14 an hour under all kinds of observing conditions.

Various important factors enter into the discussion of meteor rates. Each observed rate must be corrected by a factor compensating for the meteors not seen owing to hindrances to observation such as moonlight, clouds and mist, all of which reduce the number of meteors seen. As we have some knowledge of the number of meteors of each magnitude, an approximate correction can be made when the observer records the faintest star visible in his zenith. The amount and duration of cloudiness or mist can also be approximately compensated for. This sky factor, introduced by C. P. Olivier, is now generally accepted by all meteor workers.

Since the rate of activity varies in the course of the night, attaining a maximum about 3:00 A.M., it is, in my opinion, not correct to combine rates determined at all hours of the night in an arithmetical mean. For the purpose of this paper,

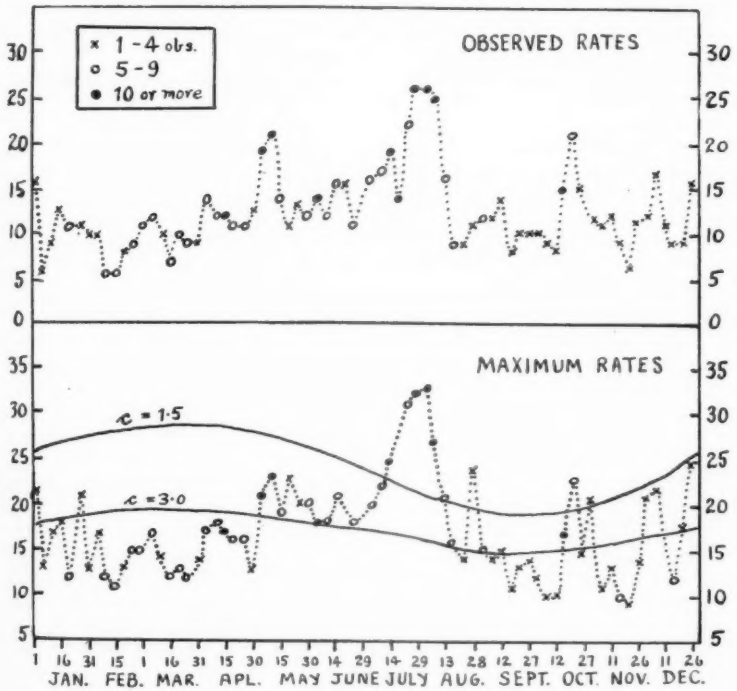


FIGURE 1

METEOR RATES DETERMINED IN NEW ZEALAND.

[The upper curve reveals the rates actually observed; the lower one is an indication of the true rates ruling, allowance being made for the time of night at which the various observations were secured.]

therefore, I have further corrected the observed rate by a time factor, increasing that rate to the maximum rate which would have been deduced if the observations had been made at 3:00 A.M. This further factor is calculated from the known rate of increase in meteor frequency in the course of the night and is checked remarkably well by figures based only on the altitude of the meteoric apex. It is necessary to point out that this correction is one entirely new to the treatment of rates and has not been employed by other meteor workers. In the graphs of the meteor rates (Figure 1) I therefore give two curves, the "maximum" rate and the "observed corrected" rate as used in previous studies of annual meteoric rates.

To illustrate graphically the variation in meteor frequencies throughout the year, the observations have been grouped in five-day periods, the only data employed being rates based on an hour or more of observation in which the sky factor did not fall below 0.5. A total of 418 observations was used. Actually a higher minimum sky factor and a minimum period of observation twice as long should have been used, but this was impossible owing to the small amount of data available. To illustrate how incomplete our records are, and the need for further observations, there remain 125 days of the year on which rates have not yet been determined.

In the upper graph of Figure 1 the curve is based on observed rates, corrected only for hindrances to observation, in the generally accepted manner. The influence of three prominent annual meteor showers, the Eta Aquarids in early May, the Delta Aquarids in July-August, and the Orionids in October, is very marked in the graph.

An experienced observer requires an average of a minute to record each meteor seen. It follows that the true rate of activity to a person merely counting and not recording will always be greater than the values shown in the curve. It has also been found impossible to make any allowance for the amount of sky watched by each observer. Dr. Astapowitsch has suggested a formula based only on area of sky watched.[6] The formula, however, is incomplete in that it makes no allowance for the position of the area watched, whether near the apex or not, nor for the latter's altitude above the horizon.

As a matter of fact New Zealand observations indicate that it does not matter greatly whether attention is confined to a small area or to the whole celestial hemisphere. In a recent special investigation members of the meteor section observing through reticules embracing a circular portion of the sky 50 degrees in diameter saw as many meteors as others covering four times that area in ordinary routine watches. I often find it necessary to watch the whole visible hemisphere, but my rates are no higher than the normal, because the greater amount of sky covered is offset by many of the faint meteors being missed.

In the lower graph of Figure 1 the observed rates have been increased, according to the time at which the observations were conducted, to the maximum rate for the night. Two lines are traced across this graph. The upper one indicates the theoretical curve of meteor frequencies, based on Hoffmeister's formula, if the meteors move with nearly parabolic velocity. The lower curve represents the theoretical curve with a velocity about twice as great. Its agreement with the observed frequency curve is much better than for the assumption of parabolic velocity. But my proof is not based on this similarity.

The altitude of the meteoric apex for the middle of each observing period was calculated for each rate used in this discussion, and the various observed rates

[6] *Astr. Bull.*, "Mirovedenie," Leningrad, December, 1929, No. 26.

were then grouped in relation to the altitude of the apex. The rich annual showers which disturb the general trend of the curve are known to be related, in two of the three instances, to periodic comets, and are therefore travelling in identical orbits and with elliptical velocities. The rates observed at the times of these showers therefore have been omitted from this portion of the discussion.

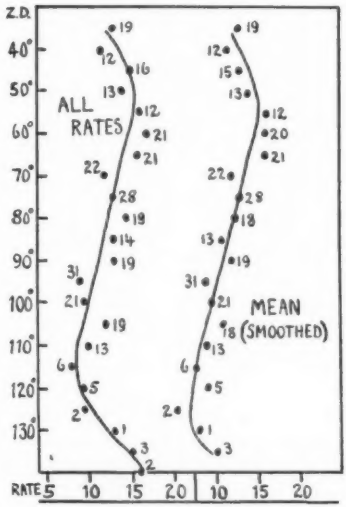


FIGURE 2

CHANGE OF RATE WITH ALTITUDE OF METEORIC APEX.

[The number beside each dot reveals the number of observations represented by the dot.]

In Figure 2 the increasing frequency of the meteors with increasing altitude of the meteoric apex is shown. The first group is the mean of all the observed rates, grouped in five-degree intervals of altitude of the apex. In the second the data have been smoothed slightly by the omission of several rates widely discordant from the remainder of their groups. The numbers of observations grouped in each altitude are shown on the graph. Above a zenith distance of 50 degrees the increase in frequency halts and then becomes a marked decrease. This falling off I attribute to the presence of dawn cutting out the fainter and more numerous meteors.

A comparison of the frequency curves of two observers made when preparing this paper revealed the interesting fact that a town-dwelling meteor observer can hope to see only seven meteors for every ten observed by his co-worker in a country district.

Taking the observed rate with the meteoric apex on the horizon as unity, the relative frequencies of meteors at various altitudes of the apex are plotted in Figure 3. The theoretical frequency curves for meteor velocities $c = 1.5$ (nearly parabolic) and $c = 3.0$ (markedly hyperbolic) are plotted against these observed

rates. The agreement between the observed frequency and the theoretical curve for hyperbolic velocity c = 3.0 is excellent.

The graph covers only 90 degrees of altitude. Below zenith distance 140 degrees the observations are too few to be of value, while above 50 degrees of zenith distance the presence of strong twilight has affected those few observations made when the apex was highest in the sky.

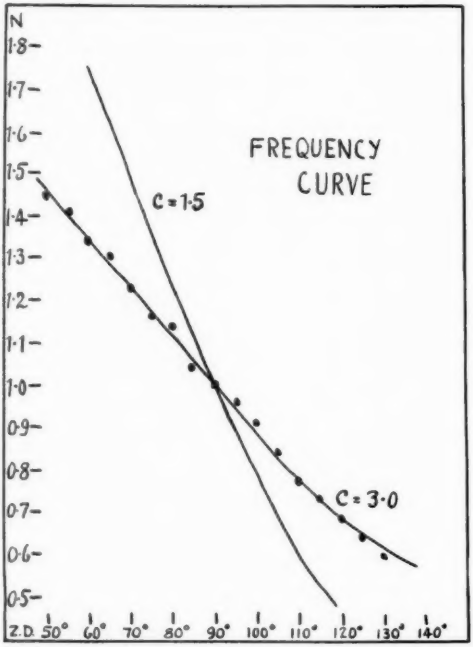


FIGURE 3

THEORETICAL AND OBSERVED METEOR RATES.

In his latest work, based on the observations of three German astronomers observing specially to determine variations in frequency, Hoffmeister's results reveal a mean velocity of c = 3.2, with which the New Zealand result, c = 3.0, is in good agreement. Since c is expressed relative to the earth's velocity, the New Zealand rates indicate that the meteors seen throughout the year and not known to be associated with comets are travelling with an average hyperbolic velocity of 55 miles a second.

While providing the first indication of the variation in the frequency of meteors in the southern hemisphere, which is of special interest to the meteor observer working there, the observations secured in New Zealand appear to confirm the brilliant theoretical work of Hoffmeister on the markedly hyperbolic velocities of sporadic meteors.

Definitions in Meteoric Astronomy

(Second Note)

By C. C. WYLIE

In an earlier paper, *Contributions of the University of Iowa Observatory*, Number 1, page 31, POPULAR ASTRONOMY, **38**, 506-507, 1930, we gave the more important definitions of meteoric astronomy as they were given in Webster's dictionary, together with illustrations of the use of the terms. Essentially the same definitions were published later by Leonard, POPULAR ASTRONOMY, **42**, 477, 1934.

Let us now repeat these definitions, using Webster's *Collegiate Dictionary*, copyright 1936. The use of the 1936 dictionary makes some of the definitions differ a little from the earlier wording.

THE WEBSTER DEFINITIONS

Meteor. A transient celestial body that enters the earth's atmosphere with great velocity, incandescent with heat generated from the resistance of the air.

Meteorite. A stony or metallic body that has fallen to the earth from outer space.

Meteoroid. One of the countless small solid bodies in the solar system which become meteors on entering the earth's atmosphere.

Fireball. A luminous meteor, resembling a ball of fire.

Shooting Star. A *meteor.*

Bolide. A brilliant *meteor,* especially one which explodes.

The definitions in the Webster dictionaries probably are based on the usage of Newton and others who were leaders in the field of meteoric astronomy forty or fifty years ago. In recent years, however, some have been using the word *meteorite* where the definitions call for *meteoroid* or *meteor.*

To understand better these definitions, and the loose usages, let us compare *meteor* with the common word *tree.* For a large *meteor* much of the *meteoroid* will survive and reach the ground as *meteorites.* From a single large *meteor* several hundred *meteorites* may drop. For a large *tree,* most of the trunk can be cut into *boards.* From a single large *tree,* several hundred *boards* may be cut.

Let us consider some usages of the words *meteor* and *meteorite,* and compare with similar usages of the words *tree* and *board.* (See POPULAR ASTRONOMY, **43**, 464, 1935; **44**, 195, 1936; and **45**, 45, 1937.)

LOOSE USAGES OF "METEORITE"

It is said that the fall of a large iron *meteorite* produced Meteor Crater in Arizona. A similar statement would be that a large maple *board* (instead of *tree*) fell during a storm and crushed an automobile. The first statement would lead a reader to assume that the "transient celestial body that enters the earth's atmosphere with great velocity, incandescent with heat" should be called a meteorite, rather than a meteor. The second statement would cause a reader unfamiliar with our language to assume that the large woody perennial plant should be called a board rather than a tree. Either is confusing.

Pictures of *meteors* sometimes appear with the caption "The Fall of a *Meteorite.*" A similar caption would be "The Making of a *Board,*" under the picture of a *tree.* Either is misleading, to say the least; but no doubt the writers of the first caption call the meteor of the picture a meteorite.

Some writers use the word *meteorite* collectively, meaning *meteorites.* With

these writers, the "Tilden metorite," may refer to all the stones dropped by the Tilden meteor, or it may refer to any one of the Tilden meteorites.

Some writers use the word *meteorite* in its strict sense, and also for any *meteor* large enough to drop *meteorites*. This is equivalent to using the word *board* in its strict sense, and also for any *tree* large enough to produce *boards*. Because of this usage, writers of popular books and textbooks for our public schools list both *meteors* and *meteorites* as heavenly bodies. One reads that the solar family includes the sun, moon, planets, asteroids, satellites, comets, *meteors* and *meteorites*. This is equivalent to saying that among the common farm animals are horses, hogs, chickens, *cattle*, and *steaks*.

Restricting the Definitions

Meteor. The definition of Webster is satisfactory. The word *meteor* often is used loosely when strictly speaking the *meteoroid* is referred to. For example, a writer may refer to an iron *meteor* the diameter of a golf ball. This usage is the same as referring to an oak tree of diameter twelve inches. Readers should understand that the nucleus of the meteor is the size of a golf ball, without the surrounding spray of sparks. They should understand that the trunk of the tree is twelve inches in diameter, without the leaves and twigs. This should not lead to confusion and does not appear objectionable.

Meteorite. The definition of Webster is satisfactory if one keeps in mind that after the bursting of the meteor the non-luminous stone or iron is a *meteorite* while it is falling.

The various loose usages of meteorite referred to previously are equivalent to using the word board for, (1) board correctly defined, (2) the trunk of a tree, (3) a large tree, and (4) a pile of boards cut from a single tree. If these loose usages of the word *meteorite* were adopted the words *meteor* and *meteoroid* might well be dropped, but to avoid confusion it would be necessary to define the term meteorite almost every time it was used.

Meteoroid. The definition in Webster is satisfactory. The nucleus or solid part of the *meteor* before bursting can be referred to as the *meteoroid*. In most popular writing, *meteor* is used loosely instead of *meteoroid*. This does not cause much confusion, but in technical discussions the term is useful.

Fireball. To the definition in Webster add that the meteor must be at least as bright as Venus, or at least as bright as magnitude —4.

Shooting Star. To the definition in Webster add that the meteor must be not brighter than Venus, that is, not brighter than magnitude —4.

Bolide. The definition in Webster is not satisfactory since, strictly speaking, meteors do not explode. Many will interpret the definition as meaning a meteor which bursts. This was not the intention of the astronomers of fifty years ago. Professor Young used the terms *bolide* and *detonating meteor* as synonomous. A detonating meteor is a bolide regardless of whether or not observers see it burst. Because of the confusion it is safer to avoid the word *bolide* and use the synonomous term, *detonating meteor*.

University of Iowa, October 11, 1938.

Contributions of the Society for Research on Meteorites

Edited by FREDERICK C. LEONARD,
Department of Astronomy, University of California at Los Angeles

President of the Society: H. H. NININGER, Colorado Museum of Natural History and American Meteorite Laboratory, Denver
Secretary of the Society: ROBERT W. WEBB, Department of Geology, University of California at Los Angeles

The Abnormal Penetration of the Norfork, Arkansas, Iron

By LINCOLN LA PAZ,
Department of Mathematics, The Ohio State University, Columbus

Abstract (and Introduction).—The Norfork, Arkansas, iron recently described by Nininger,[1] belongs probably in the select category of North American irons of witnessed fall. While it is a normal siderite in other respects, certain surface features are unusual, and the observed depth of penetration into the earth of four feet is much greater than one would expect to find in the case of a meteorite weighing only 1050 grams. The purpose of this paper is to give some quantitative indication of the discrepancy between the reported penetration of Norfork and the calculated probable penetration of a spherical iron meteorite weighing only 1050 grams. In view of the magnitude of this discrepancy, it seems most improbable that the small iron mass under consideration attained the reported depth by actually forcing its own way into the earth. The most probable explanation of the observed abnormal penetration is that the Norfork fragment entered the earth in the wake of a much larger mass, from which it was disengaged approximately at the instant of impact. From a study of the peculiar form and superficial features of the Norfork specimen, Nininger has already been led to conjecture that it "represents a corner of a large mass which was detached just as the main body penetrated the soil." It is shown in what follows that the weight of the unrecovered portion of the fall may lie between 27.8 and 286 kilograms.

§1. *The Penetration of Spherical Siderites.*—While the occasional occurrence of a hole of meteoritic origin inclined to the vertical or of meteoritic showers, shows that meteorites may retain a small horizontal component of velocity down to contact with the earth, it seems to be true in general, as was first emphasized by G. von Niessl, that meteorites, during the latter part of their flight through the atmosphere, have a motion quite like that of any other falling body, subject to only the attraction of the earth and the resistance of the air. A very elementary argument suggests that the penetration of such a body will be proportional to the cube root of its mass. This conclusion is substantiated not only by penetration-mass data, but also by the theoretical considerations of Fisher[2] based on experimental work in exterior ballistics carried on in France. For the penetration p of a spherical iron meteorite of mass M, Fisher deduced the formula,

$$p = c \times M \times \log (1 + k \times M^{1/3}),$$

where c and k are constants, but remarked that, until more exact penetration-mass data become available, the slowly varying logarithmic factor must be treated as a constant in the applications. Consequently, as previously suggested,

$$p = C \times M^{1/3}, \tag{1}$$

where C is the product of c and the constant logarithmic factor. For M expressed in pounds and p in inches, Fisher regarded the value $C = 5.63$ as giving a *lower bound* for the penetration of iron meteorites into the average earth target. The penetration-mass data published by Nininger[3] satisfy (1) very well with C taken as 8. As far as reliable data for irons of witnessed fall are concerned, it appears that an *upper bound* for p is obtained by choosing $C = 12.2$ in (1). But, then, on taking 8 as the density δ of the irons, and passing for convenience to the metric system, it is found that to a high degree of approximation, p satisfies the easily remembered inequalities

$$6\,r \leqq p \leqq 13\,r. \tag{2}$$

We shall check this result by giving in what follows a tabular comparison of the observed penetration p_0 and the bounds on p calculated from (2), for a typical series of siderites of witnessed fall and reliably observed mass and penetration:

	M (in g.)	r (in cm.)	(2)	p_0 (in cm.)
Mazapil, Mexico	3,950	4.9	$29.4 \leqq p \leqq 63.7$	30.0
Braunau, Bohemia	23,600	8.9	$53.4 \leqq p \leqq 115.7$	100.0
Cabin Creek, Arkansas	47,400	11.2	$67.2 \leqq p \leqq 145.6$	91.4
Treysa, Germany	63,280	12.4	$74.4 \leqq p \leqq 161.2$	160.0

The low value for p_0 in the case of Cabin Creek, Arkansas, is accounted for probably by the fact that this iron, in falling, cut through limbs on a large pine tree. The large value of p_0 for Treysa, Germany, would seem to be due to the fact that approximately half of its path in the earth was through loose, light-leaf mold and loam. The preceding tabulation supports the view that, even for siderites falling on very diverse earth-targets, (2) can be depended upon to give bounds between which the actual penetration will fall.

§2. *Application to the Norfork Siderite.*—The density of the Norfork iron is not given by Nininger. However, since the average value of δ for siderites is near 7.8, it is easy to verify that, in the present connection, it is entirely permissible to adopt 8 as the value of the density. Since $M = 1050$ g., it follows that $r = 3.2$ cm. Hence, from (2), the penetration p would be expected to lie between 19.2 cm. and 41.6 cm., *i.e.*, between 7.6 in. and 16.4 in. The observed penetration of 121.9 cm. (48 in.) lies so far beyond the upper bound for the probable penetration, that it seems unquestionable that something "ran interference" for the small Norfork iron in its plunge into the earth. It is natural to assume that the necessary hole was opened by the main mass of the siderite, of which the recovered specimen is merely a fragment disjoined approximately at the moment of impact. If this interpretation of the situation is the correct one, then, by reversing our use of (2), we can secure information as to the probable weight of the main mass of the Norfork fall, on assuming it to have been approximately spherical in shape. Thus, since (2) implies that

$$p/13 \leqq r \leqq p/6, \tag{3}$$

it follows that the weight of the unrecovered portion of the fall, on assigning to it a penetration of only 122 cm., lies between 27.8 and 286 kg. That such a splendid meteorite should be irrevocably lost—the conclusion reached by Nininger after repeated efforts to locate the place of fall—must bring keen regret to all meteoriticists.

REFERENCES

[1] Nininger, H. H., *C.S.R.M., P.A.*, **45** (1937), 562, and **1**, No. 3 (1937), 62.
[2] Fisher, W. J., *Proc. Nat. Acad. Sci.*, **19** (1933), 286.
[3] Nininger, H. H., *N.S.R.M., P.A.*, **42** (1934), 515.

Notice of the Sixth Annual Meeting

The Sixth Annual Meeting of the Society has been scheduled by the Council to be held in connection with the regular winter meeting of the American Association for the Advancement of Science in Richmond, Virginia, at 10:00 A.M. and at 2:00 P.M. on Thursday, December 29, and on Friday, December 30, 1938. A joint session has been arranged with Section E of the Association, "Geology and Geography," for December 29, at 2:00 P.M., on the subject of "The Origin of the Carolina 'Bays.'" The outstanding success of our last joint session with Section E, on the occasion of the Fifth Annual Meeting at Denver, Colorado, in June, 1937, indicates that no interested member should miss the coming session.

Members who are engaged in any kind of research on meteorites or meteors are cordially invited to present papers at this meeting. Titles and abstracts should be forwarded as soon as possible to the Secretary. Papers may be presented by members *in absentia* as well as by those in attendance at the meeting.

ROBERT W. WEBB, *Secretary*

September 20, 1938

Bibliography of Papers Read at the Symposium on "Meteorite Craters" in 1937

Following is a bibliography (believed to be complete up to date) of the eight papers numbered 6 to 13 inclusive, which were delivered at the joint symposium of the Society and Section E (Geology and Geography) of the A.A.A.S., on "Meteorite Craters," at the Fifth Annual Meeting in Denver, Colorado, in June, 1937. (See the "Report of the Fifth Annual Meeting," *C.S.R.M., P.A.*, **45**, 454-6, and *C.S.R.M.*, **1**, No. 3, 45-8, 1937.) This bibliography is included here to facilitate reference to these papers and/or their abstracts. In what follows, *P.G.S.A.* refers to the "Proceedings of the Joint Sessions of Section E, American Association for the Advancement of Science, and the Geological Society of America in 1937," by Howard A. Meyerhoff, Secretary, published in *Proc. Geol. Soc. Am.*, 1937, pp. 299-330 (June, 1938); this publication contains abstracts only, of all of these papers.

6. "A Summary of the Findings Resulting from the Exploration, the Geophysical Survey, and the Test Drillings at Meteorite Crater, Arizona," by W. F. Bingham, *The Pan-American Geologist*, **68**, 196-8, 1937 (résumé), and *P.G.S.A.*, 305.

7. "Geological Theories on the Origin of the Carolina 'Bays,'" by Frank A. Melton, *P.G.S.A.*, 312.

8. "Meteorites and the Craters on the Moon," by Leonard J. Spencer, published in full in *Nature*, **139**, 655, Apr. 17, 1937, and abstracted (by H. H. Nininger) in *P.G.S.A.*, 315.

9. "Observations during the Excavation of a Meteorite Crater," by H. H. Nininger, *C.S.R.M., P.A.*, **46**, 110, 1938, and *P.G.S.A.*, 313 (both abstracts).

10. "Meteorite Craters and Structures," by Claude C. Albritton, Jr., and J. D. Boon, *P.G.S.A.*, 305-6.

11. "On the Concept of Earth Shells," by R. T. Chamberlin, *P.G.S.A.*, 307.

12. "Age Determination of Meteorites," by W. D. Urry, *P.G.S.A.*, 317.

13. "Meteorite Contributions to Sediments," by Alfred C. Lane, *P.G.S.A.*, 311.

VARIABLE STARS

Variable Star Notes from the American Association of Variable Star Observers

By LEON CAMPBELL, Recorder

The A.A.V.S.O. Meeting: The twenty-seventh annual meeting of the A.A.V.S.O. was held at the Harvard Observatory, as has been the custom since 1915, on October 15, 1938. About seventy-five members and friends were present.

On the previous evening, the members were guests of the Bond Astronomical Club at its annual meeting, when various Harvard delegates to the International Astronomical Union meeting, held in Stockholm this past summer, reported on the activities of the several commissions into which the Union is divided. Professor B. J. Bok reported on "Absorption Problems" which had been an important topic of debate at the Stockholm meeting. Miss Jenka Mohr told of the discussions and resolutions of the Variable Star Commission, and the activities of the Meteor Commission were recounted by Dr. Doritt Hoffleit. Professor D. H. Menzel described the work of Dr. Lyot of Meudon with the coronagraph in photographing, at times other than during a total eclipse, the solar chromosphere and corona. The results obtained by Dr. Lyot were truly remarkable, and his work opens up a great field for further study of the sun's outer atmosphere and its hitherto hidden appendages.

The Saturday morning meeting of the A.A.V.S.O. was occupied chiefly with reports of officers and committees. Tributes were paid to the memory of those recently deceased: to Professor E. W. Brown by Dr. Dirk Brower, to Dr. S. K. Proctor by Mr. C. B. Carpenter, and to Mr. J. S. Andrews by Mr. David W. Rosebrugh.

Dr. Alice H. Farnsworth has accepted the appointment of Chairman of the Occultation Committee of the association, and Mr. Joseph L. Woods of Baltimore, Maryland, has been made the new Chairman of the Photographic Committee. Mr. F. Hartmann of Springfield Gardens, Long Island, New York, continues as Chart Curator, and Mr. D. F. Brocchi, of Seattle, Washington, as Chairman of the Chart Committee.

The Recorder's report, presented informally, described the events of the past year, in particular the acquisitions of the Olcott and Yalden libraries, numbering nearly a thousand titles of books and pamphlets. Reference was also made to the continued use of the slide collection, some 1250 slides having been loaned for lecture purposes on thirty-seven occasions. The telescope loan department reported the receipt on loan, for re-loan to an association member, of a 3-inch telescope from Mr. Noah W. McLeod, and the loan to Mr. Carl Whittier of Reading, Massachusetts, of the Olcott 3-inch telescope.

Announcement was made of a coöperative scheme for recording aurorae by experienced observers of the association under the dirction of Dr. Gartlein of Cornell University.

Four numbers of *Variable Comments* have been issued during the year: number 12 contains the Sixth Annual Report of the Recorder; numbers 13 and 14 give accounts of the Twenty-sixth Annual and the Twenty-seventh Spring meetings held at Harvard Observatory and Brown University, respectively; and in number 15, the Recorder discusses the A.A.V.S.O. and its problems.

The annual summary of observations received at headquarters proved of exceeding interest. As far as annual totals are concerned, the year just completed showed 61,500 observations received from 162 observers, as against a previous high, in 1935, of 54,309 observations. Eppe Loreta of Bologna, Italy, heads the list of contributors, with a total of 4757 observations, followed by E. H. Jones with 4248, and W. S. Houston with 3864. Five observers made between 2000 and 3000 estimates, each, and ten observers made between 1000 and 2000 observations each. Thirty-five observers contributed more than 500 observations each, with a total of 51,000. Some ten thousand estimates were made by the remaining one hundred and twenty-seven observers, indicating the value of even a few observations from the casual observer in contributing to the completenss of the data received at headquarters.

The following papers were presented:
First Fruits of the Harvard Variable Star Bureau, C. Payne-Gaposchkin.
The Variable DF Cygni, Margaret Harwood.
The Ernst Collection of Sundials at Harvard, R. N. Mayall.
Progress of the Milwaukee Astronomical Society Observatory, E. A. Halbach.
Southern Short Period Variable Stars, 1920-26, A. W. J. Cousins.
The Eclipsing Variable β Lyrae, S. Gaposchkin.
The 1936-37 Meeting of the A.A.V.S.O. (motion pictures), L. J. Boss.
Visiting Other A.A.V.S.O. Members (motion pictures), C. B. Carpenter.

The following were elected to the council for a term of two years: Dirk Brouwer of Yale Observatory; Joseph W. Meek of Tucson, Arizona; Leo J. Scanlon of Pittsburgh, Pennsylvania; Joseph L. Woods of Baltimore, Maryland.

Newly elected officers are: President, Charles W. Elmer; First Vice President, Helen S. Hogg; Second Vice President, Dirk Brouwer; Secretary, David W. Rosebrugh; Treasurer, Percy W. Witherell; Recorder, Leon Campbell.

The sessions closed with the annual banquet. Professor R. H. Baker, now spending a Sabbatical year at Harvard, was the guest speaker, and told us of his visit to Uraniborg, the island observatory of Tycho Brahe.

After dinner, addresses were made by Miss Annie J. Cannon and by Miss H. H. Swope and President C. W. Elmer, who gave us more details concerning the I.A.U. meeting. Dr. Z. Kopal of Prague brought greetings from his observatory.

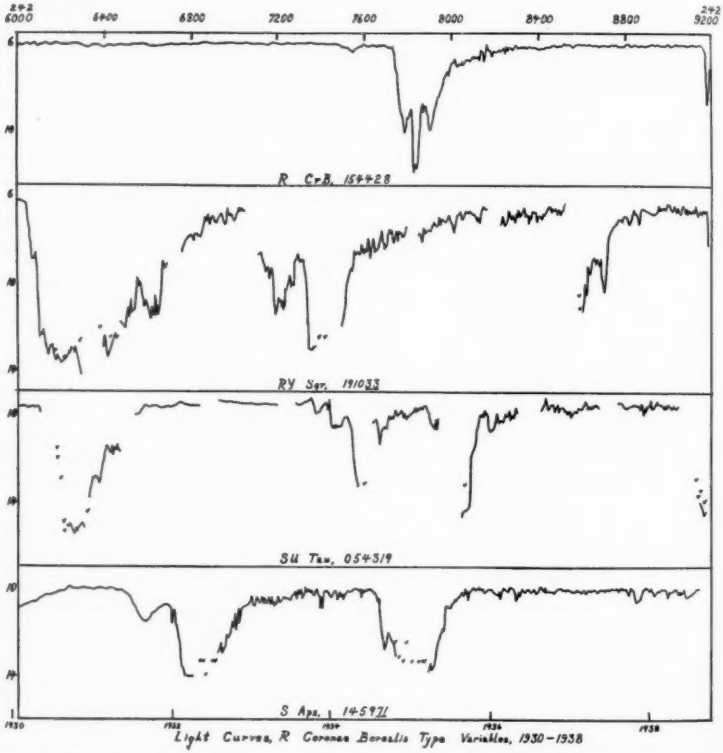
On Sunday, a score of members visited the recently erected observatory of Dr. S. Gaposchkin, who has an A.A.V.S.O. 10-inch reflector at his disposal for the observation of special variable stars.

The R Coronae Borealis Type Variables: Three of the four R Coronae Borealis type variables, now under close scrutiny by the A.A.V.S.O. observers, have been "acting up" during the past few months. First, word was received from W. S. Houston that SU Tauri, 054319, had suddenly decreased from approximately magnitude 9.5 to less than magnitude 13.0 during August. Later observations show a minimum magnitude of 14.5, with no present indication of an increase in brightness. The previous decrease in magnitude occurred in 1935, and since the summer of 1936 the variable has fluctuated slightly around magnitude 9.5.

On September 25, word was received from D. W. Rosebrugh that R Coronae Borealis, 154428, had decreased in light to magnitude 6.6. Because of the garbling of the telegraphic message, the full importance of this fact was not revealed until several days later. R Coronae Borealis progressively decreased until magnitude 8.8 was reached on October 8; since that date, the brightness appears to have slowly increased to magnitude 7.0 on October 18.

This most recent drop on the part of R Coronae Borealis is somewhat analogous to that observed in 1924, which followed the deep minimum of 1923, with the exception that the interval since the 1934-35 deep minimum has been four years, instead of a year and one half.

Word just received from Joseph W. Meek announces the decrease in light of RY Sagittarii, 191033, another R Coronae Borealis type variable, to magnitude 8.0 on October 13, 1938. Two days later the magnitude had decreased to 8.6, according to observations of Mr. L. C. Peltier. This indicates that of the four best known R Coronae Borealis type variables observed by the A.A.V.S.O., only one, S Apodis, 145971, is apparently now at maximum. This star was observed at minimum in 1934-35, and since September, 1935, it has been at or near maximum magnitude, 10.0.



Light Curves, R Coronae Borealis Type Variables, 1930–1938

A plotting of the light curves of these four R Coronae Borealis type variables is shown herewith.

Dr. Louis Berman showed some years ago that the atmosphere of R Coronae Borealis is composed, mainly, of carbon. Carbon is the least volatile of all the elements, and has a rate of evaporation, at a given temperature, less than that of any other element, with a corresponding stronger tendency to condense from the gaseous state.

Mr. John O'Keefe, formerly a graduate student at Harvard and now studying at Yerkes, suggests a possible explanation for the peculiar behavior of the R Coronae Borealis stars, namely, that these giant stars may occasionally eject matter from their atmospheres, as does our own sun, and that this ejected material may be chiefly carbon, rather than either calcium or hydrogen. Such a cloud, when once formed, would obscure the light of the star considerably; and it can be shown that it would require only about one per cent of the total amount of carbon in the star's atmosphere to bring about a decrease in the light of the star amounting to ninety-nine per cent. The amount of this ejected material would be an important factor in the determination of the amount of fading away of the light. The slow progressive brightening of the star would be due to the gradual dissipation of the cloud of carbon, with more or less intermittent changes in the density of the cloud, as evidenced by the great irregularities usually observed in the light curve after minimum has been attained.

Mr. O'Keefe goes on to state that, in view of the very small change in the observed spectrum of the variable at minimum, the loss of light is due more to obscuration than to any fundamental change in the star itself. The only change observed in the spectrum of R Coronae Borealis at minimum is the appearance of a few bright lines.

Now that three of these R Coronae Borealis type variables are below normal maximum brightness, it behooves astronomers to attempt to confirm this interesting hypothesis of Mr. O'Keefe.

Gamma Cassiopeiae: According to observations by Dr. S. Gaposchkin, made on October 18, the interesting variable star Gamma Cassiopeiae was at magnitude 2.5, approximately one-half magnitude fainter than normal brightness. Comparing this observation with the light curve published in the December, 1937, issue of POPULAR ASTRONOMY, in these notes, it will be seen that Gamma Cassiopeiae appears to have a range of at least one magnitude.

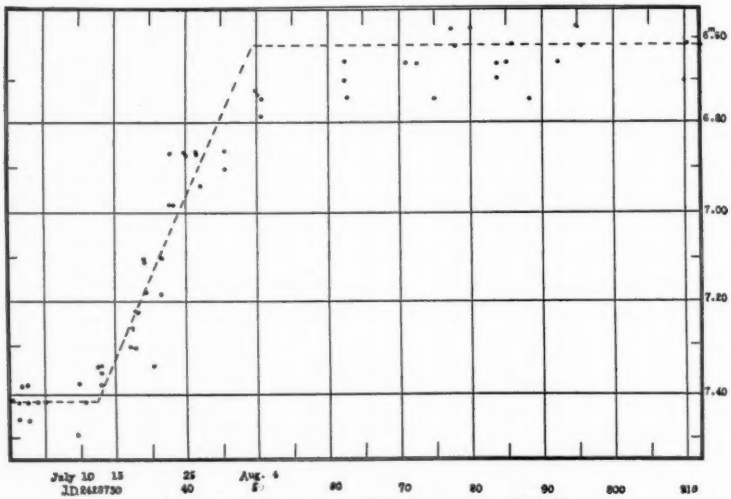
The Ascending Branch of the 1936-37 Minimum of VV Cephei: In a paper presented at Ann Arbor, Dr. S. Gaposchkin showed a light curve of the ascending branch of the twenty-year period eclipsing variable VV Cephei. The previously recorded light curve of the star, giving little of the descending branch and only a part of the actual minimum, had been published because of the desire to call immediate attention to this interesting supergiant star and to stimulate current observations.

With the complete light curve now available, it may be seen that an additional large variation of the light may deform the systematic shape of the minimum. There is also some slight evidence that, as in the case of Zeta Aurigae, the first and fourth contacts of the eclipse are not sharply defined, because of absorption of light by the atmosphere of the red supergiant.

New observations of the third and fourth contacts during the 1936-37 eclipse have been secured by Dr. Gaposchkin, and are represented in the accompanying figure. The straight line determines the duration of the partial eclipse.

He derives the following results: the probable end of the eclipse fell on the night of August 3, 1937 (J.D. 2428749.4), and the beginning of the partial eclipse on July 2, 1937 (J.D. 2428727.8). The observed times are about five days later than had been predicted. It is regrettable that the beginning of the 1936-37 minimum is not covered by visual or photographic observations. The observations on January 8, 1936, show the star near maximum, and there then follows a period of six months without observations, until June 3, 1936, when the star was at mini-

mum. Since there is a definite additional variation of light, as can be seen even from the figure, spectroscopic and photometric observations obtained on a single night, considered without reference to all other nights, may give an erroneous impression that the star is at minimum.



ASCENDING BRANCH OF VV CEPHEI, IN 1936-37.

Observers and Observations during July-September, 1938: New observers, as follows, have contributed their observations during the quarter ending October 1, 1938: G. Economou, Manchester, New Hampshire; C. L. Ferguson, South Charleston, West Virginia; H. M. Harris, South Portland, Maine; Leon Laskaris, Warren, Pennsylvania; C. Seavageau, Detroit, Michigan; C. H. Whittier, Reading, Massachusetts; and E. G. Williams, Radcliffe Observatory, Pretoria, South Africa. Besides these A. R. Ball, John Bell, Jr., E. B. Heckenkamp, E. Needham, R. P. Nelson, and H. Siebel, all of the Milwaukee Astronomical Society Observatory, have contributed initial reports.

Observer	July Var.	July Est.	Aug. Var.	Aug. Est.	Sept. Var.	Sept. Est.
Adamopoulos	..	..	16	18	..	..
Ahnert	35	523	..	..	..	..
Albrecht	7	13	12	16	32	51
Ancarani	11	34	8	12	13	19
Armfield	..	..	..	..	4	4
Baldwin	91	175	45	213	..	..
Ball, A. R.	..	..	11	14	3	3
Ball, J. J.	..	..	..	..	2	2
Ballhaussen	15	18	..	..	..	..
Bappu	..	..	24	49	..	..
Blitzstein	9	13	..	..	7	18
Blunck	22	31	40	50	61	67
Bouton	28	32	23	25	42	52
Brocchi	69	155	45	85	72	172
Buckstaff	10	41	17	104	19	150
Callum	60	150	48	143	60	91
Cameron	6	7	2	2	4	5
Carpenter	125	127	92	92	125	129
Chandra	136	278	..	..	89	168
Chartier	20	22	..	..	26	36
Christman	..	..	..	..	15	23
Cousins	..	..	24	178	47	136
Dafter	9	15	8	31	6	25
Diedrich	26	52	30	38	38	94
Economou	..	..	5	5	3	11
Ellis	24	38	12	16	24	35
Ensor	20	99	66	83	65	97
Escalante	..	..	15	17	7	7
Evans	25	45	38	50	50	72
Fairbanks	..	..	..	..	14	24
Ferguson	5	7	8	14	14	19
Fernald	23	118	24	108	29	158

Observer	July Var.	July Est.	Aug. Var.	Aug. Est.	Sept. Var.	Sept. Est.
Focas	..	..	59	88	..	..
Forster	8	21	..	..	..	..
Franklin	15	18	14	24	12	15
Gausewitz	2	2	..	..	..	..
Gregory	130	234	..	..	45	59
Gruenwald	..	..	5	5	..	..
Halbach	80	105	84	102	96	112
Hamilton	..	..	12	12	16	30
Harris	..	..	..	..	1	1
Hartmann	98	174	124	165	91	99
Hassler	..	..	12	18	..	..
Heckenkamp	..	..	..	..	3	3
Herbig	97	229	117	404	76	153
Hiett	12	25	31	60	30	100
Hildom	13	16	24	67	35	122
Holwer	..	..	..	..	7	7
Holt	40	50	4	21	50	61
Houghton	85	177	79	123	78	247
Houston	36	114	107	401	125	408
Howarth	10	12	15	22	..	..
Irland	17	17	..	..	8	8
Jones, E. H.	89	328	31	59	108	448
Jones, M. D.	..	..	..	..	8	20
Kearons	22	32	45	68	47	81
Kelly	7	10	9	12	15	20
Keuziak	4	4	13	13	10	10
Kirkpatrick	31	79	32	114	40	166
Knott	..	..	..	..	4	10
deKock	51	221	55	230	53	181
Koons	..	..	70	79	85	97
Kotsakis	30	36	..	..	..	..
Kozawa	5	12	..	..	..	..
Laskaris	5	10	..	..	..	..
Lizarraga	..	..	..	..	5	5
Loreta	115	449	128	448	150	468
McLeod	24	29	23	33	27	47
McNabb	..	..	2	6	..	..
Meek	20	293	19	109	30	169
Millard	..	..	31	57	28	45
Monnig	6	6	3	3	..	..
Murphy	..	..	18	34	21	49
Needham	11	12	17	17	14	14
Nelson	..	..	..	..	10	17
Parker	11	13	15	15	22	24
Peck	48	296	12	34	..	..
Peltier	163	192	182	235	195	265
Prinslow	12	12	8	9	21	49
Purdy	9	12	5	32	7	15
Pursell	..	..	4	4	3	4
Rademacher	4	5	2	3	4	10
Recinsky	17	66	14	38	15	43
Rosebrugh	15	70	10	49	12	54
de Roy	13	63	16	53	16	49
Ruhloff	..	..	..	..	4	4
Russell	..	..	13	15	29	65
Ryder	..	..	..	..	16	16
Schmidt	..	..	3	3	25	28
Seavageau	..	..	5	5	..	..
Seely	11	37	13	50	18	58
Siebel	..	..	..	..	2	2
Shafer	3	9	..	..	5	14
Shultz	..	..	..	..	6	6
Sill	17	17	11	11	30	30
Smith, C. W.	5	10	..	..	..	..
Smith, F. P.	18	20	23	47	39	50
Smith, F. W.	3	7	4	8	5	11
Smith, I. R.	26	26	27	27	27	28
Smith, L.	..	..	6	6	..	..
Thorndike	4	4	..	..	10	10
Topham	6	6	5	5	..	..
Treadwell	10	10	11	13	24	89
Webb	15	16	29	31	35	35
Weber	9	9	..	..	13	17
Whittier	..	..	4	5	11	21
Williams	11	143	..	..	..	..
Woods	..	..	9	26	8	17
Yamasaki	2	2	5	5	11	11
Totals		5743		4887		5958

October 20, 1938.

Notes from Amateurs

The New Haven Amateur Astronomical Society

The New Haven Amateur Astronomical Society is progressing with well-attended meetings, growing interest, and enthusiasm in the many divisions of its interest and work.

Dr. Everett Rademacher (a member of our society) addressed the group on October 8 on the subject "Astronomy and the Mind of Man," and in his discourse presented the subject in a very interesting manner, showing the very close relationship between the human mind and many astrological and astronomical matters.

Mr. William Glowacki (also a member of our society) at a special meeting addressed the group on "Surface Markings on Mars" and said in part that the first drawings of Mars were made by Huygens in 1659. He sketched the various

landmarks in Martian discovery, illustrating salient points by slides loaned by the Van Vleck Observatory. Three epochs of discovery were noted, those associated with the names of Galileo, Herschel, and Schiaparelli. The last mentioned was the first to discover the famous canals and thereby precipitated an argument that persists even to this day.

Mr. Glowacki emphasized the fact that the faint planetary detail at the limits of vision and perspective cannot be studied photographically with much profit. The canals of Mars can be seen only with the eye through a good telescope though not necessarily large telescopes, and then only at certain few places on the earth with favorable seeing conditions. Observers must be skilled and well experienced to see these faint markings.

Several slides illustrating Simon Newcomb's work on the subjective side of this phenomenon were of particular interest. He made it apparent from many slides shown that an eye conditioned by a preconceived notion could easily integrate many faint impressions to give the sharp lines that typify the canals as drawn by Lowell.

In the speaker's final summary he showed that Mars, though smaller, differs mainly from the earth in being colder and dryer. Earthmen could possibly live on Mars though with difficulty, but of all the planets in our system it is the best suited for life as we know it and will always hold our interest. In 1940 Mars will be 36 million miles distant and well situated for observation.

FRANK R. BURNHAM.

October 21, 1938.

An Astronomical Gyroscope

Through the researches of Sperry and others the gyroscope has grown to be an instrument of widely varying application. The astronomer has found little use for this wonderful mechanism as far as I know. It seemed to me that its remarkable properties could be applied astronomically as a means of telescope drive of unerring accuracy.

When a gyroscope is mounted properly it will turn once on its polar axis every day. That is, when it is rotating in a plane coincident with the plane of the celestial meridian or any line of celestial longitude.

The diurnal motion of the earth causes this apparent rotation, the plane of rotation of the gyroscope remaining stationary in relation to the celestial sphere.

A telescope attached to the polar axis of this mounting, provided it is balanced nicely enough, will apparently follow a star perfectly, *i.e.*, neglecting the error of atmospheric refraction which can be eliminated by use of the slow motion in R.A. and Dec.

I have used a mounting of this type successfully for a number of years. A camera of 32 inches focal length will follow without correction for three or four hours provided the area of sky under observation is near the meridian. I have incorporated a modified double-slide plate-holder in the tail-piece of this camera and have found that the images of my photographs are as round and sharp as the quality of the lens will permit.

The gyroscope in use at present is a fifty pound affair consisting of two discs of tool steel 20 inches in diameter and 2 inches thick lathed to a high degree of accuracy. These are mounted on either side of the protruding armature shaft of a 1/16 H.P. A.C. motor turning at about 6,000 R.P.M. The motor does not run all the time, but is alternately turned on and off every minute by a clock-driven

relay. The disc momentum is sufficient to keep the centrifugal force well within the limit of instability. The motor has a set of high grade ball-bearings as has the polar axis, insuring a minimum of vibration and a saving in power consumption.

The sole difficulty with this apparatus is that it takes 20 minutes or more to get the gyroscope to the required speed of 6,000 R.P.M., but the accuracy derived from it is well worth the wait. Of course, a more powerful starting motor could be geared in, but this would entail unnecessary expense which a little foresight on the part of the observer would omit.

A clamp in R.A. or a friction disc arrangement serves admirably for changing the hour angle just as on standard clock driven mounts. This and a vernier or double-slide tail-piece on the telescope or camera will make any desired correction in adjustment in H.A. The usual Dec. adjustments need no modification. Any type of mounting can be built on the polar axis or the gyroscope can be built into any type of mounting according to the ingenuity of the experimenter.

I would be interested to hear from anyone who has tried this scheme or has seen or heard about it. It seemed to me to be such an excellent solution to this problem of telescopic drive that I thought other amateurs would be interested in it.

Another property of the gyroscope is that it is pole seeking. That is, if the gyroscope is mounted in a set of mariner's gimbals and is permitted to run at top speed it will precess until it points exactly to the pole. This takes about six hours or more according to the accuracy of the mounting. When the gyroscope ceases to precess clamp your gimbals and using a surveyor's transit you can set your equatorial exactly on the celestial pole by simply adjusting the polar axis to parallelism with the observed position of the gyroscope. This method gives a relatively quick and easy procedure to follow in setting any equatorial mounting. I have used it successfully many times even on polar axes as much as twelve feet long.

An amateur's observatory equipped with instruments driven and adjusted by gyroscopic method can readily cope with the problems of professional astronomers. Such problems as stellar spectroscopic analysis, photography of extra-galactic nebulae, measurement of close doubles, and many other types of work requiring accurate driving can be well done by this apparatus if made properly.

573 Monroe Street, Brookly, New York. WILLIAM S. VON ARX.

General Notes

The Rittenhouse Astronomical Society of Philadelphia held a meeting of the Society on Friday, October 14, in the Hall of The Franklin Institute, Benjamin Franklin Parkway at 20th Street. An address on the subject "Sky Splendors and Sky Puzzles" was given by Dr. W. J. Humphreys, Collaborator, United States Weather Bureau, Emeritus Professor of Physics, George Washington University.

Occultations during the Total Lunar Eclipse of November 7-8, 1938

$\lambda_0 = +82^\circ\ 0'$, $\phi_0 = +39^\circ\ 0'$

On November 7, 1938, occultations of a sixth magnitude planet and a seventh magnitude star will occur in the eastern and central parts of the United States while the moon itself is eclipsed. The tables above give data which furnish a

DATA FOR COMPUTING TIMES

Star	Imm.:	T_0(GCT)	A_T	B_T	C_T	D_T	E_T	F_T	G_T	H_T
Date (1938) Mag.	Em.:	T_0(GCT)	A_T	B_T	C_T	D_T	E_T	F_T	G_T	H_T
		h m	m	m	m	m	m	m	m	m
Uranus		22 47.9	+52	+215	+10	+13	+38	+1	+6	+1
Nov. 7 6.0		23 26.6	−31	+ 53	+11	−29	−18	0	−1	0
BD+15°414		22 39.6	+28	+130	+10	+ 1	+24	−2	−3	+1
Nov. 7 6.9		23 32.3	0	+142	+ 9	−22	− 6	+2	+4	−1

DATA FOR COMPUTING POSITION ANGLES

Star	Imm.:	P_0	A_P	B_P	C_P	D_P	E_P
Date (1938) Mag.	Em.:	P_0	A_P	B_P	C_P	D_P	E_P
Uranus		30°	− 91°	−266°	+3°	−29°	−12°
Nov. 7 6.0		296	+109	+272	−4	+25	+15
BD+15°414		71	− 62	−194	+7	+ 4	+24
Nov. 7 6.9		256	+ 81	+201	−7	− 8	−22

means of readily obtaining the times and position angles at immersion and emersion accurate to within 1^m5 and 5°, respectively, for a point in longitude λ, latitude ϕ where the following conditions are fulfilled, D being the duration obtained by subtracting the time of immersion from that of emersion when the values found from the formula for the times which is to be given below are used:

1. $|\lambda - \lambda_0| \leq 14°0$; $|\phi - \phi_0| \leq 10°0$.
2. $D \geq 30^m0$.

Then the required Greenwich civil times $T_{\lambda,\phi}$ and position angles $P_{\lambda,\phi}$, measured from the north point of the moon's limb toward the east, are given by

$$\begin{aligned} T_{\lambda,\phi} = T_0 &+ 10^{-2}[A_T(\lambda-\lambda_0) + B_T(\phi-\phi_0)] \\ &+ 10^{-3}[C_T(\lambda-\lambda_0)^2 + D_T(\lambda-\lambda_0)(\phi-\phi_0) + E_T(\phi-\phi_0)^2] \\ &+ 10^{-4}[F_T(\lambda-\lambda_0)^2(\phi-\phi_0) + G_T(\lambda-\lambda_0)(\phi-\phi_0)^2] \\ &+ 10^{-5}[H_T(\lambda-\lambda_0)^3(\phi-\phi_0)^2] \\ P_{\lambda,\phi} = P_0 &+ 10^{-2}[A_P(\lambda-\lambda_0) + B_P(\phi-\phi_0)] \\ &+ 10^{-3}[C_P(\lambda-\lambda_0)^2 + D_P(\lambda-\lambda_0)(\phi-\phi_0) + E_P(\phi-\phi_0)^2] \end{aligned}$$

where $(\lambda - \lambda_0)$ and $(\phi - \phi_0)$ must be reckoned in degrees and tenths of a degree.

If condition (1), above, is satisfied but $0^m0 \leq D < 30^m0$, the results given by this method should be regarded as inaccurate; on the other hand if condition (1) is satisfied but $D < 0^m0$, the occultation should not be expected at the given place, though it may occur with a brief duration. Rapidly increasing errors must be expected if one applies these formulas to points at greater and greater distances outside the region defined by (1).

The partial phases of the planet's eclipse will each last about one-tenth of a minute or more, the exact durations depending largely upon the difference between the position angles at immersion and emersion.

JACOB HERMANN.

Route 3, Kenosha, Wisconsin.

'38 down the Centuries in Astronomy*

1038.—Death of the Arabian astronomer, physicist, and mathematician, Alhazen (965-1038). In the field of optics he ranks first among the scholars of antiquity and the Middle Ages. His principal work in its Latin translation, *Optica* (1572), exerted a considerable influence on western science and was frequently quoted with great respect by Kepler.

1638.—In Paris a number of scholars began to hold regular meetings to discuss

*Extracted from the Italian of Pio Emanuelli in *Coelum* for March, 1938, by Dr. H. Loss of Carleton College.

questions of astronomy, mathematics, and physics. Out of these meetings, first held in the convent of Father Marin Mersenne, grew the French Academy of Sciences. Among those who attended the early meetings were Pascal, Descartes, Roberval, Gassendi, Fermat, and the English philosopher Hobbes.

1638.—Birth of James Gregory (d. 1675). The Gregorian telescope bearing his name was made known to the world by his *Optica Promota* (1663). This type of reflecting telescope was universally used throughout almost the whole of the eighteenth century.

As early as 1638 Father Mersenne had suggested the use of a spherical reflector, but Descartes, to whom he proposed his idea, dismissed it as ridiculous, and Mersenne laid it aside. Gregory seems not to have had any inkling of Mersenne's project.

1738.—Birth of Wm. Herschel (d. 1822), discoverer of the planet Uranus and founder of sidereal astronomy. He discovered 800 new double stars and 2400 new nebulae. In 1783 he propounded the view that our sun has a movement of translation toward the constellation Hercules. The point in the heavens fixed upon by him as the "apex" of this motion differs only by a few degrees from that which modern investigators have determined.

1838.—Birth of Arthur Auwers (d. 1915), director of the Potsdam Observatory; his name (with that of Gill) is linked with the determination of solar parallax, and even more closely with his masterly compilations of the first stellar catalogues.

1838.—Birth of S. W. Burnham (d. 1921), the greatest observer of double stars in the nineteenth century. He devoted close to 50 years to the task and discovered 1340 new double stars.

1838.—Birth of Geo. W. Hill (d. 1914), astronomer and mathematician, noted for his works on the theory of the Moon, the theory of Jupiter and Saturn, and dynamic astronomy.

1838.—Pietro Tacchini (d. 1905) devoted himself to the study of solar physics. Director of the Observatory of Palermo and later of that of the Roman College, he contributed largely to the study of solar prominences which he observed daily for more than 30 years. He may be considered the founder of the Societa degli Spettroscopisti Italiani.

1838.—The Germans, Beer and Mädler, publish the first map of the planet Mars in the *Astronomische Nachrichten* of April, 1838.

1838.—Till this year it was generally held that stellar parallaxes were too small to be perceptible with measuring instruments. At the Observatory of Dorpat, W. Struve undertook the determination of the parallax of α Lyrae with a parallactic telescope constructed by Fraunhofer. His observations from 1835 to 1838 totalled 96, and gave as a final result the value $0''.262 \pm 0''.025$. The present-day value of the parallax of α Lyrae is $0''.121 \pm 0''.004$.

The problem was attacked by Bessel at Königsberg in 1837, using his famous Fraunhofer heliometer. Bessel selected 61 Cygni. After a first series of observations carried on between August, 1837, and October, 1838, Bessel took his heliometer apart to make some repairs, and, mounting it again, proceeded to a new series of measurements which ran from October, 1838, to March, 1840. The result he obtained for the parallax of 61 Cygni was: $0''.348 \pm 0''.010$. The present-day value is $0''.299 \pm 0''.003$.

Book Reviews

The Advancing Front of Science, by George W. Gray. (Whittlesey House, McGraw-Hill Book Company, Inc., 330 West 42nd Street, New York. $3.00.)

The fact that this book was selected as the book of the month by the Scientific Book Club is at once a striking testimonial concerning its status in the judgment of persons wholly capable of evaluating it. It is the conviction of the writer that the judgment of the experts will be the judgment of the average reader as well. The volume is not filled with technicalities but is written in a lucid style which gives it the character of a narrative and not of a formal exposition.

The natural sciences, the biological sciences, and the psychological sciences are all taken up in order. The readers attention is held throughout the three hundred fifty-three pages by the feeling that he is really coming close to the things about which he is reading. Science, its methods and results, are no longer an abstraction to be viewed objectively, but something which comes into the everyday experience of each one.

The imposing array of names of scientists, listed in the preface, indicating the persons consulted by the author in the preparation of the several chapters gives the reader the assurance that here is to be found the most recent pronouncements by the authorities. The facts assembled from these numerous sources are fused into a whole by the genius of the author and the account becomes a unit. A careful perusal of this volume will put one in touch with the most important phases of present day developments in the rapidly advancing fronts of science. Having read the book we heartily approve the statement from the announcement of this book: "The reader will understand anew through these pages the spirit, the purpose, the ingenious methods, and the amazing successes which make the research laboratory the most romantic spot on earth at the present time—and perhaps the most significant."

It is a beautifully bound volume and, both in appearance and content, it will lend dignity and prestige to the libraries in which it is given a place.

Annales D'Astrophysique.—This is the name given to a new publication, the first issue of which appeared in January, 1938, and is to be issued quarterly. It is published under the auspices of the Bureau of Astrophysical Research of the French National Foundation of Scientific Research. The first issue contains an account of the first international conference in astrophysics held in Paris in July, 1937, and addresses by Mr. Jean Perrin, Mr. Ernest Esclangon, Mr. Bertil Lindblad, Mr. Otto Struve, and Mr. Henri Mineur delivered on that occasion. It contains also a number of papers on the general subject of the absorption of light in interstellar space. It is, of course, in the French language.

Relativity and Robinson, by C. W. W. (The Technical Press, Ltd., 5 Ave Maria Lane, Ludgate Hill, London. 3s 6d.)

This small-sized book of a little more than one hundred pages claims to be "A treatise for very simple people." This, no doubt, commends it to many persons who, probably quite properly, consider themselves as such in regard to the abstruse relativity doctrines. The person, Robinson, mentioned in the title is the represen-

tative of this large group, and speaks for it. However, he does not speak very much but listens quietly and patiently to the explanations made by the Padre and the Professor. The Mathematician is dismissed in the first chapter and returns only on the last page, because he is needed for further advancement into the subject. The several items, properties of various kinds of space, relative motion, simultaniety of events, gravitation, usually present in a discussion on *relativity*, are introduced here. The treatment of them is brief and simple. In a word, the volume, small enough to be read easily at one sitting, is stimulating and informative for anyone not already familiar with the ideas presented, and who is willing to expend the effort in thought necessary to comprehend it.

Bergedorfer Spektral-Durchmusterung, Band 2, +45°.

This large sized volume of 384 pages is, as is indicated in the title, the second in a series. The completed series is to cover the 115 Selected Areas of Kapteyn, in the northern hemisphere. It contains for all stars of the thirteenth magnitude or brighter the spectrum derived from plates made with the Lippert-Astrographic telescope at Hamburg by A. Schwassmann, and the magnitudes determined at the Kapteyn Astronomical Laboratory in Groningen from plates taken at the Harvard College Observatory. It represents a large amount of labor and will be useful to future workers in spectral analysis.

Van Vleck Observatory Publications.—Volume I of this series has appeared this year. It consists of 277 pages and is devoted chiefly to the work involved in the parallax determination of 130 stars. The results of this work were published in three lists in the *Astronomical Journal*, but more detail is furnished in this volume. Volume I contains also, quite appropriately, a history of the observatory, a record of the ceremony of dedication, a description of its equipment, and the method of carrying on its program.

Professor Frederick Slocum, the director, and his colleagues, Dr. Stearns and Professor Sitterly, deserve congratulations and commendation upon furnishing this attractive and significant volume to the astronomical literature.

La Notion de Temps, by Ernest Esclangon. (Gauthier-Villars, Paris. 20 fr.).

In this work the author endeavors to differentiate clearly between two kinds of time which he designates as *metaphysical time* and *physical time*. The former is intuitional and the latter, an artificial structure of science. The discussion is philosophical and mathematical and requires a well-defined background for its understanding. The treatise touches upon the relation between physical time and the ideas grouped under the term *relativity*.

The work is concluded with some astronomical considerations concerning the apparent structure of the universe.

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